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CONCRETE ENGINEERS' HANDBOOK

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P R E F A C E

India is making steady progress in all directions and in civil engineering she has some of the largest construction works in the world to her credit. It may, however, be said without any fear of contradiction that her strength of civil engineers is much less than her requirements. Except on government and semi-government projects and in cities like Bombay where qualified consulting engineers are available, a very large percentage of public building activity is today managed by the humble maistry or overseer or a contractor with little or limited theoretical background. Even in the case of qualified engineers we are afraid there may be several who have to construct a concrete structure only occasionally in their career in a drainage, irrigation, or water supply department. It may not be expected of them to remember all the long formulæ of reinforced concrete design together with the methods of their application.

This handbook is written specially for the convenience of such people. A specialist in concrete engineering who invariably has his own tables of reference may not find this book indispensable but we are sure where preliminary investigations and estimates are to be made he will save considerable time by reference to various tables in the handbook.

Large portions of India are alluvial tracts where good broken stone and coarse sand are not available and the use of imported material is very costly. The local material, even though of sub-standard quality, has to be used. Similarly in case of steel, it is necessary to use bars made from scrap steel by local rolling factories. In such places it is advisable to use lower stresses and hence tables, charts, etc. giving concrete sections

according to the old L.C.C. Regulations (1909) which may appear too orthodox to one unfamiliar with mofussil conditions in India have been given purposely. Where conditions are favourable, higher stresses are certainly recommended.

Before concluding this preface it would not be out of place to say a word or two about the most important and much discussed problem of the design of concrete mixes. This aspect of concrete engineering is practically new to the vast majority of Indian engineers who so far were working on the basis of arbitrary mixes found suitable by practice. A method of rationally designing concrete mixes has been given in this handbook and we trust Indian engineers will make extensive use of it henceforth, and let us have the reports of their findings.

Thanks are due to Mr. N. H. Mohile, B.E., M.I.E. (India), M.I. Struct. E. (Lond.) of this Association whose efforts are mostly responsible in bringing out this handbook.

The book is published with a sincere hope that it will fulfil the long felt need for a concise reference book on the design and technology of concrete.

CONCRETE ENGINEERS' HANDBOOK

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CHAPTER 1

MATERIALS

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CHAPTER I

MATERIALS

1.1 PORTLAND CEMENT.

1.1.1 DEFINITION.

Portland Cement is defined as a product obtained by intimately mixing together calcareous and argillaceous and/or other silica, alumina, or iron oxide bearing materials, burning them at a clinkering temperature and grinding the resulting clinker. After burning no material other than gypsum or air entraining agents is added.

1.1.2 VARIOUS KINDS OF CEMENT.

1.1.2.1 Rapid Hardening (also called High Early Strength Cement).

(a) *Materials used for manufacture*: Same as ordinary cement but more carefully prepared and carrying higher lime content.

(b) *Burning Operations*: At a temperature higher than that of ordinary cement.

(c) *Grinding*: Finer than ordinary.

(d) *Setting properties*: Same as ordinary type.

(e) *Hardening properties*: Attains in 3 days the strength of 28 days old normal cement and so saves cost of moulds, etc., by about 30 per cent.

1.1.2.2 } White Cement and Coloured Cement. 1.1.2.3 }

(NOTE.—White cement is not made in India. Snowcrete, Atlas, etc., are generally used.)

(a) *Materials used for manufacture*: Pure limestone free from any iron content.

(b) *Strength, etc.*: Up to B.S.S., but slightly less than normal cement.

Coloured cement is made by mixing white cement with inorganic colours about 5 to 10% at the time of grinding.

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1.1.2.4 Aluminous (also called High Alumina) Cement.

[Not made in India. Imported brands are: *Ciment Fondu* Lightning (U.K.), *Lumnite* (U.S.A.) etc.]

(a) *Manufacture*: Mixture of bauxite and lime is heated to fusion at high temperature.

(b) *Setting*: Sets within one hour.

(c) *Hardening*: Very rapid. 100 days strength of ordinary cement is developed within 24 hours.

(d) *Special qualities*: Immune from attacks of sea-water, sulphate bearing waters, frost, etc. Forms excellent refractory concrete stable up to 1500°C.

Precautions: Contamination with ordinary cement to be avoided.

1.1.2.5 Blast Furnace Cement.

(a) *Manufacture*: Clinker of normal Portland Cement is ground with about 65% of granulated slag. The slag should in no case be more than 65%.

(b) *Properties*: Same as ordinary cement.

NOTE: Slag cement is different from blast furnace cement being a mixture of lime and blast furnace slag ground together.

1.1.2.6 Masonry Cement.

(a) *Manufacture*: Ordinary Portland Cement is mixed with hydrated lime or calcium or aluminium stearate or paraffin oil.

(b) *Properties*: Gives more workable and plastic mortar and hence more suitable for masonry and plaster works.

1.1.2.7 Low Heat Cement.

(a) *Properties*: Less heat is evolved during setting. Hence more suitable for large mass concrete works, where heat of hydration does not dissipate easily and so cracks the concrete after cooling.

1.1.2.8 Air Entraining Cement.

(a) *Manufacture*: Rosin and Vinsol resin or vegetable fats and oils such as tallow and olive oil and other fatty acids such as stearic and oleic acids are ground with ordinary cement.

(b) *Properties*: Development of microscopic air bubbles while setting forms minute voids in the concrete and increases its resistance against freezing and sealing action of salts like Calcium Chloride, etc. Three to five per cent air trapped in the concrete in the form of tiny individual bubbles improves the

MATERIALS

workability of the concrete, permitting a reduction in the water cement ratio, reduces shrinkage and improves durability, etc.

1.1.2.9 Pozzolanic or Silica Cement.

(a) *Manufacture*: Ordinary cement clinker and pozzolana (about 30%) are ground together. The pozzolana may be natural such as diatomaceous earth or pumice, or artificial such as burnt clay.

(b) *Properties*: The pozzolana reacts with free lime in the concrete which otherwise is affected by corrosive water. Addition of pozzolana also improves such qualities of the concrete as water-tightness and fire resistance. The concrete is also of low heat type.

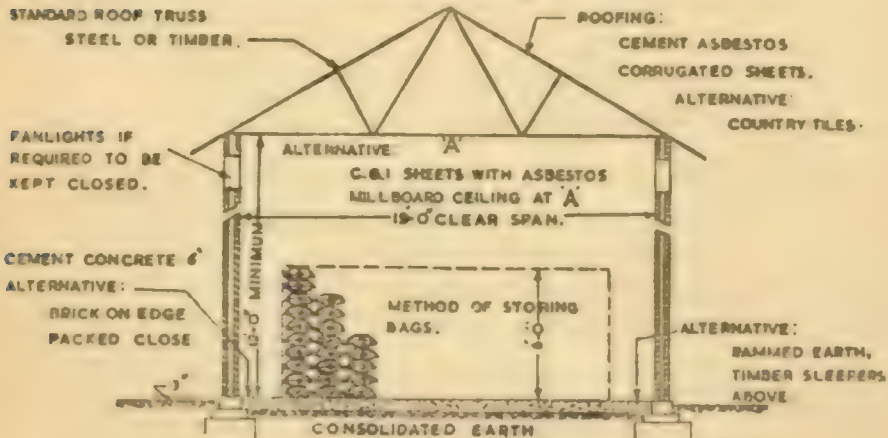
1.1.2.10 Modified Cement.

Gives lower heat of hydration than normal cement and has improved resistance to sulphates.

1.1.3 STORAGE

All possible precautions for keeping moisture away are necessary. The storage shed should have a pucca floor raised at least 6 inches from ground, with air-tight doors and windows. Bulk storage is preferable for longer interval. Fig. 1-1 gives a design of an ideal godown.

SUGGESTED BUILDING FOR STORING 40 TONS PORTLAND CEMENT



SECTION ON A-A

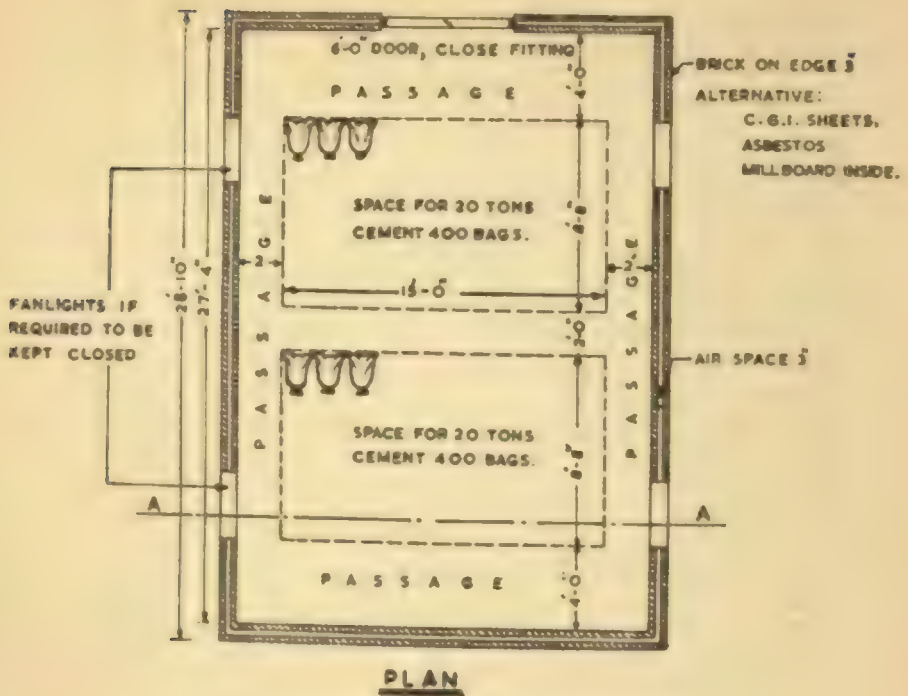


Fig. 1-1.

Reduction of Strength in Storage.

The following reduction may be expected at 28 days:—

After storage of 3 months 20% minimum.

After storage of 6 months 30% minimum.

After storage of 1 year 40% minimum.

After storage of 2 years 50% minimum.

1.1.4 STANDARD SPECIFICATIONS.

Summary of specifications controlling the manufacture of various cements, used in India is given on the facing page:—

PROPERTIES OF CEMENT

TYPE OF CEMENT		ORDINARY PORTLAND CEMENT	RAPID-HARDENING PORTLAND CEMENT (1)	PORTLAND BLAST-FURNACE CEMENT	LOW-HEAT PORTLAND CEMENT	HIGH-ALUMINA CEMENT
STANDARD		1 5 269 (1951)	1 5 269 (1951)	B 5 N 9146 (1947)	B 5 N 91370 (1947)	B 5 N 915 (1947)
FINENESS (4)	MINIMUM RESIDUE BY WEIGHT ON B-S SIEVE NO 170 (27)	10 PERCENT	5 PERCENT	10 PERCENT	—	8 PERCENT
	MINIMUM SPECIFIC SURFACE (6) SQ CM PER GRM	2250 (1600)	3250 (1700)	2250	3200 (1700)	2250
MINIMUM TENSILE STRENGTH (3) LB. PER SQ. IN.	1 DAY	—	300	—	—	—
	3 DAYS	300	450	300	—	—
	7 DAYS	375	—	375	—	—
MINIMUM COMPRESSIVE STRENGTH (3) LB. PER SQ. IN.	1 DAY	—	1000	—	—	6000
	3 DAYS	1600	3500	1600	1000	7000
	7 DAYS	2500	—	2500	1600	—
	28 DAYS	—	—	—	3750	—
SETTING TIMES (HOURS)	INITIAL	NOT LESS THAN ½			41	42 ½
	FINAL	NOT LESS THAN 10			½ 10	½ 2 AFTER INITIAL SET
SOUNDNESS	EXPANSION (LE CHATELIER)	NOT MORE THAN 10 mm (0.40 IN)				½ 1 mm (0.40 IN)
HEAT OF HYDRATION	7 DAYS	NONE SPECIFIED			CALS PER GRM	NONE SPECIFIED
	28 DAYS				½ 65 ½ 75	
CHEMICAL COMPOSITION	$S = SiO_2$ $A = Al_2O_3$ $F = Fe_2O_3$ $C = CaO$	$\frac{C}{2.85 + 1.7A + 0.65F}$ 40-66 $\frac{A}{F}$ 40-66	BLAST-FURNACE SLAG ½ 65 PERCENT (CEMENT CLINKER TO COMPLY WITH B-S-NR 12)	$C \geq 2.45 + 1.2A + 0.65F$ $A \geq 1.95 + 1.2A + 0.65F$ $A \geq 40-66$	$A \geq 0.85$ $C \geq 1.3$ $A \geq 32 PER CENT$	
	ADMITTURE AFTER BURNING	NONE (EXCEPT GYPSUM OR WATER OR AIR ENTRAINING AGENTS (1% MAXIMUM))		NONE (EXCEPT GYPSUM AND WATER)		
	MgO	½ 5 PER CENT	½ 5 PER CENT	½ 5 PER CENT	—	
	SO ₃	½ 2-75 PER CENT	½ 5 PER CENT	½ 2-75 PER CENT	—	
	INSOLUBLE RESIDUE LOSS ON IGNITION	½ 1 PER CENT ½ 4 PER CENT				—
NOTES		1 "HIGH EARLY STRENGTH CEMENT" 2 NOMINAL SIZE OF APERTURE 0.0035 IN. 3 ALTERNATIVE TESTS STRENGTH AT ANY AGE MUST BE GREATER THAN STRENGTHS AT EARLIER AGES 4 ALTERNATIVE TESTS (EXCEPT FOR LOW-HEAT PORTLAND CEMENT) 5 AS SO ₃ : ½ 2 PER CENT ; AS SULPHIDE: ½ 1-2 PER CENT. 6 BRACKETED FIGURES FOR TURBIDIMETER METHOD				

Fig. 1-2.

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1.15 ADULTERATION.

Field Test for Adulteration.

(a) A sample of doubtful stuff should be burned for about 20 minutes on a steel plate heated by a stove. Adulterated sample changes its colour, while unadulterated cement remains unchanged.

(b) Make small pats, say $2'' \times 2'' \times \frac{1}{4}''$ with adulterated and genuine cement. Pats made with doubtful cement can be broken easily with pressure of your fingers.

It is always advisable to send the sample to laboratory for full analysis and tests.

1.16 USEFUL MEMORANDA ON CEMENT.

1 jute bag contains $110\frac{1}{2}$ lbs. of cement (about 1.2 cft.)

1 ton of Portland Cement—20 jute bags—24 cft.

1 barrel of cement weighs 376 lbs.

6 barrels of cement make 1 ton (Metric).

1 cft. of cement loosely filled weighs 85 to 90 lbs.

1 cft. of cement tightly packed weighs 110 lbs.

Atlas white cement (American) weighs 94 lbs. per cft.

Snowcrete white cement (English) weighs 85 lbs. per cft.

Ferrucrete Rapid Hardening Cement weighs 75 lbs. per cft.

Ciment Fondu Aluminous Cement weighs 87 lbs. per cft.

1 cubic yard of cement—1.112 tons.

1 cubic foot of loose cement neat as cement paste will cover about 10.4 sq. ft. (1 inch thick).

1 cft. of neat cement (90 lbs.) will cover 2.2 sq. yds. ($\frac{1}{4}''$ thick).

1 cft. of neat cement (90 lbs.) will cover 1.9 sq. yds. ($\frac{1}{2}''$ thick).

1 cft. of neat cement (90 lbs.) will cover 1.7 sq. yds. ($\frac{3}{4}''$ thick).

1 cft. of neat cement (90 lbs.) will cover 1.4 sq. yds. ($1''$ thick).

1 cft. of neat cement (90 lbs.) will cover 1.1 sq. yds. ($1\frac{1}{2}''$ thick).

1 cft. of loose Portland Cement will make:

4.3 cft. of 1 : 2 : 4 concrete.

5.0 cft. of 1 : $2\frac{1}{2}$: 5 concrete.

5.8 cft. of 1 : 3 : 6 concrete.

7.5 cft. of 1 : 4 : 8 concrete.

MATERIALS

1.2 AGGREGATES.

1.2.1 DEFINITION.

Inert material such as sand, pebbles, gravel, crushed stone, etc., which is mixed with Portland Cement and water to produce concrete or mortar is called aggregate.

1.2.2 GENERAL REQUIREMENTS.

Necessary characteristics: The aggregates must be clean, dense, hard, durable, structurally sound, capable of developing good bond with cement, weather-resisting and unaffected by water. Aggregates for road work must have good wearing qualities. When fire-proof construction is needed the aggregates must possess fire-resisting qualities. In case of industrial by-products, blast furnace slag which is a non-metallic product consisting essentially of silicates and aluminosilicates of lime and of other base obtained along with iron in a blast furnace, must not contain more than 40% lime. Cinders must be obtained as a product of high temperature combustion and must not contain more than $\frac{1}{2}\%$ of sulphur and 1% of sulphates. Similarly coke breeze must be free from sulphur and unburnt coal.

1.2.3 SITE TREATMENT OF AGGREGATES.

Site Treatment.—This is necessary if the aggregate as supplied is short of requirement as regards cleanliness and grading. Screening can be done by hand or mechanically to adjust the grading. If the material requires cleansing, washing may be resorted to, but precautions against loss of fine material should be taken. A simple arrangement for mechanical washing device is shown diagrammatically in Fig. 1-3.

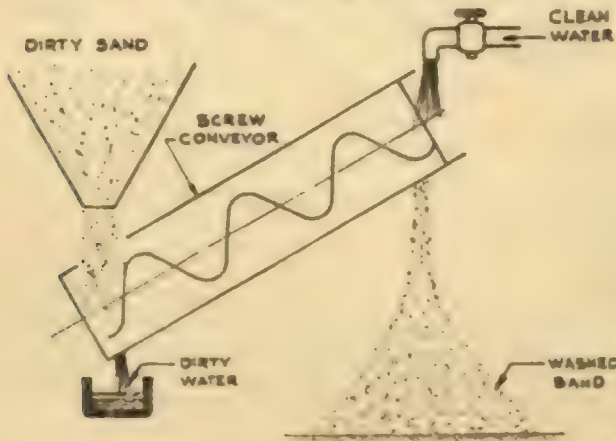


Fig. 1-3

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1.2.4 STORAGE OF AGGREGATES.

Precautions.—Avoid storing on dusty, muddy or grassy spots. Dumps must be protected from exposure to dust. Old steel sheets or wooden planks may be used as platforms for storage. On large works storage bins may be used. When stored on ground, the bottom layer of aggregates, say 3" deep, should be rejected. Correct and incorrect methods of handling and storing aggregates are shown diagrammatically in Fig. 1-4.

CORRECT



Place aggregates in stock piles in individual units not larger than a truck load and in suitable layers to prevent segregation. [They should not be allowed to run down slopes as shown in B at right].

INCORRECT

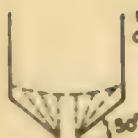


A
TRANSPORTED
BY CONVEYOR

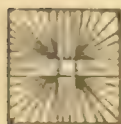


B
TRANSPORTED
BY TRUCK

A. Belt Conveyor, B. truck unloading material at the top of pile and allowing same to run down slope.



PROPER TYPE
OF BIN BOTTOM



FLAT

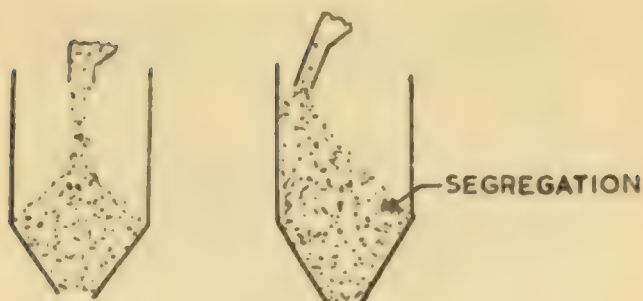


IMPROPER SLOPE



When bins are used for storing aggregates they should have bottoms sloping about 50° in all directions and corners of the bottom should be properly rounded. [Flat or insufficiently sloping bottomed bins are not suitable].

MATERIALS



While filling the bins material should be made to drop in the centre and not against sides to avoid segregation.

Fig. 1-4.

The aggregates should not segregate into various sizes while storing, otherwise there will be serious difference in the quality of concrete produced.

1.25 TESTS ON AGGREGATES.

1.25.1 Laboratory Tests.

- (a) Sieve Analysis.
- (b) Determination of clay, silt and dust.
- (c) Determination of organic impurities.
- (d) Specific gravity and absorption.
- (e) Aggregate crushing test.
- (f) Bulk density or unit weight.
- (g) Determination of voids.
- (h) Test for coal and lignite.

Selection of sample.—Care is necessary to have a fairly representative sample. A large quantity, say 12 cwt., should be collected by taking one cwt. from different heaps. This should be reduced to required quantity by method of quartering as shown in Fig. 1-5.

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Fig. 1-5. Method of quartering aggregates for sampling.

Minimum quantity.—Different tests require different minimum quantity of aggregates as given below:—

Test	To be supplied to the laboratory	To be tested
Sieve analysis		
2½" to 1½" aggregates	1½ cwt.	50 lbs.
¾" to ½" "	1 cwt.	20 lbs.
Fine "	28 lbs.	1 lb.
Determination of Clay etc.		
2½" to 1½" aggregates	1 cwt.	14 lbs.
¾" to ½" "	28 lbs.	1 lb.
Fine "	2 lbs.	1 lb.
Specific gravity and absorption		
C. aggregates	4 lbs.	2 lbs.
Fine "	"	"
Aggregate Crushing Strength		
2" to ¾" size	2 cwt.	1 cwt.
¾" to ½" size	"	14 lbs.
Fine aggregates	"	2 lbs.
Bulk density		
C. aggregate	2 cwt.	75 lbs.
fine aggregate	½ cwt.	15 lbs.
voids Test		
C. aggregate		500 ccs.
fine aggregates		100 ccs.

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(a) *Sieve Test.*—A known weight of dry aggregates is passed through a set of standard sieves of size 3", 2½", 1½", ¾", ½", ⅜", 3/16"; in case of coarse aggregate, and Nos. 7, 14, 25, 52, 100 in case of fine aggregates, and percentage retained is noted.

(b) *Determination of clay, etc.*—A certain fixed quantity of material is sieved through No. 7 sieve. Material retained on the sieve is washed with sodium oxalate solution of 0.8 grs. per litre strength. This solution is again sieved through No. 7 sieve, and 150 m.l. of this solution taken. This solution is mixed with the material that has passed the No. 7 sieve. A soft rubber pestle is used for mixing the material without causing any attrition. The mixture is kept in a sedimentation tube and after 100 seconds a certain amount is taken in a pipette. This quantity is evaporated in a crucible and weight of residue taken. From this data the percentage of clay, etc., is known.

(c) *Organic Impurities.*—A 12 oz. medicine bottle is filled to 4½ oz. mark with sand and 3% solution of sodium hydroxide is added up to 7 oz. mark. The colour of the liquid is compared with standard colour chart.

(d) *Specific Gravity.*—A certain sample of material properly washed to remove dust is dried in an oven and weighed. The sample is then immersed in distilled water and entrained air from the sample is removed by gentle rodding. The sample is then placed in a wire basket suspended in water and weighed. The weight of saturated sample immersed in water is thus obtained. The specific gravity is calculated from the result.

(e) *Aggregate crushing strength.*—A weighed quantity of aggregates is placed in a metal cylinder fitted with a plunger. This plunger is subjected to a specified compression and the aggregate is sieved to remove the material crushed by the compression. The weight of the fines formed is expressed as a percentage of the total sample.

(f) *Bulk density.*—Material held by a container of unit volume when filled under specified conditions is found out.

(g) *Voids.*—A cylindrical metal measure is filled one-third with water and dry aggregate is then added and tamped to exclude air. The process is repeated till the measure is filled to the top and further water added till the measure overflows. The volume of water added gives the volume of voids in the aggregate, from which the required percentage can be calculated.

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(d) *Coal and Lignite*.—This is found by removing the particles by floatation in a liquid with a specific gravity of 2 (made from a mixture of carbon tetrachloride and acetylene tetrabromide).

1.25.2 Field Tests.

Sieve analysis is done in the same way as above but all the sieves are not necessary.

Silt Test.—A glass vessel is filled half with sand, and water is added up to three-fourth height. After shaking vigorously the contents are allowed to settle after one hour. This gives a fair idea about the quantity of silt in the sample.

Organic matter and void tests.—Same as laboratory tests.

1.25.3 Particle Shape and Surface Texture.

In addition to above, a report on aggregates should also contain information about particle shape and surface texture of the aggregates as per following description:—



Fig. 1-6. Characteristic specimens of concrete aggregates.

MATERIALS

(a) *Particle Shape.*

Classification	Description	Examples.
Rounded	Fully waterworn or completely shaped by attrition.	River gravel, wind blown sand, desert sand etc.
Irregular	Naturally irregular or partly shaped by attrition and having rounded edges.	Pit sand & gravels land or dug flints, cuboid rock etc.
Angular	Having well defined edges.	Crushed rock of all types.
Flaky	Material (usually angular) of which thickness is small relative to width and length.	Crushed rock of all types. Laminated rocks.

(b) *Surface Texture.*

Texture.	Example.
Glassy	Flint, vitrious sand.
Smooth	Slate, Marble etc.
Granular	Sandstone, oolite etc.
Crystalline	Fine Basalt Medium dolerite
Pitted	Coarse granite, gneiss etc.
Fine slag	Coarse slag, brick, pumice, etc.
Honey Combed	
porous	

1.2.6 MISCELLANEOUS NOTES.

Bulking of sand.—The volumetric expansion of sand due to moisture content is called Bulking. Finer sands bulk more

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than coarser varieties. As the moisture increases and the sand becomes fully saturated, it occupies the same volume as dry sand.

Type of Sand	% Moisture by weight	% Bulking by volume.
Fine	5	38
	10	32
	15	22
	20	10
	27	0
Medium	5	29
	10	22
	15	12
	20	0
Coarse	5	18
	10	12
	15	2

1.2.7 USEFUL DATA ON AGGREGATES.

Weight lbs./cft.

Fine and dry river sand (loose)	90
Medium "	95
Coarse "	100
Burnt clay ballast	70
Beach or river shingle $\frac{1}{2}$ " to $\frac{1}{4}$ "	100
Gravel—coarse loose, unscreened	115
Broken brick 2" to $\frac{1}{2}$ " gauge	80
" stone	100
Stone screening $\frac{1}{2}$ " to $\frac{1}{4}$ "	90
Broken granite 2" to $\frac{1}{2}$ "	105
Granite chipping $\frac{1}{2}$ " down	95
Coke Breeze 1" down	45
Clinker hard furnace 1" to $\frac{1}{2}$ "	70
Pumice stone	40
Blast furnace slag $1\frac{1}{2}$ " to $\frac{1}{2}$ "	90
Honey comb slag	40

MATERIALS

Voids: (Approximate percentages).

Sand (moist and fine)	..	..	..	43
Sand (coarse)	..	..	..	35
Sand (mixed)	..	..	..	38
Sand (dry mixed)	..	..	..	30
Stone screenings	..	..	..	58
Broken stone 1" and under	..	..	..	46
" 2"	..	..	..	45
" 2½"	..	..	..	41

Specific Gravity.

Trap	..	..	..	..	2.9
Granite	..	..	..	..	2.7
Slate	..	..	..	..	2.7
Gravel	..	..	..	..	2.66
Sand	..	..	..	..	2.65
Limestone	..	..	..	..	2.60
Sand stone	..	..	..	..	2.40

13. WATER.

13.1 FUNCTION OF WATER.

13.1.1 Chemical.

Water and various compounds in cement react chemically in the process of setting and hardening of cement. Portland Cement contains about 65% of lime. For complete hydration of all the lime in 100 lbs. of cement about 21 lbs. of water are required. In setting complete hydration does not take place; hence about 14 lbs. of water are sufficient.

13.1.2 Physical.

(a) Water distributes the cement evenly so that every particle of stone and sand is coated by it and brought into intimate contact with each other.

(b) Water acts as lubricant and gives workability to the mixture.

13.2 FIELD TESTS FOR WATER.

13.2.1 Acids.

Can be detected by litmus paper.

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1.3.2.2 Sulphates.

Acidify the water with dilute sulphuric acid and then add a little barium chloride solution. Formation of white precipitate indicates presence of sulphates. This should be compared with the local tap water similarly treated.

1.3.2.3 Chlorides.

Acidify water with a little nitric acid and add a few drops of 10% silver nitrate solution. A thick white precipitate indicates chlorides.

1.3.2.4 Carbondioxide.

Add a few drops of dilute hydrochloric acid. A rapid evolution of CO_2 will then take place.

1.3.3 QUANTITY OF WATER.

(a) *Mixing Concrete.*—For exact quantity, detailed information is given in chapter on proportioning of concrete, but for estimating purposes the following figures may be used.

Mix	1 : 3 : 6	1 : 2 : 4	1:1½:3½	1 : 1½ : 3	1 : 1 : 2
Dry aggregates	7½	6½	6	5½	5
Damp aggregates	6½	6	5½	5	4½

(The above figures give quantity of water in gallons per cwt. of cement.)

(b) *Other purposes.*—For washing aggregates, curing, etc., 75 to 80 gallons may be assumed per 100 cft. of concrete work.

1.3.4 USEFUL DATA.

One cft. of water	= 6.23 Imperial Gallons.
	= 7.48 U.S.A. Gallons.
	= 62.4 lbs. (at 60° F.).
One Imperial Gallon	= 4.55 litres.
	= 4 qrts.
	= 0.16 cft.
	= 1.2 U.S.A. Gallon.
One U.S.A. Gallon	= 0.83 Imperial Gallon.
One ton of water	= 1 cubic metre.
	= 244 Imperial Gallons.
	= 35.9 cubic feet.
One cft. of sea water	= 64.1 lbs.

MATERIALS

1.4. REINFORCEMENT.

1.4.1 STEEL REINFORCEMENT.

Steel Reinforcement comprises of:

- (a) mild steel rods,
- (b) cold drawn mild steel wire,
- (c) twisted bars, single or double,
- (d) welded fabrica,
- (e) expanded steel,
- (f) ribbed mesh steel sheets acting as shuttering also,
and
- (g) R.S. sections such as joists, channels, rails, etc.

1.4.2 GENERAL REQUIREMENTS.

- (a) Freedom from surface defects.
- (b) Freedom from rust scales, (moderate surface rusting may be permitted).
- (c) Freedom from oil, greuse or paint; (lime or cement wash is permissible).

1.4.3 STRUCTURAL REQUIREMENTS AND OTHER PARTICULARS.

- (a) M.S. rods
- (b) Cold drawn M.S. Wire

Material	Size D = Dia- meter In Inches	Minimum Stress Tons □"		Elongation		Diameter of Bend
		Yield	Ultimate	Length	% Age	
Mild Steel	Over 1"	Not spe- cified.	28	4D	24	3D
	1" To 1"			8D	20	2D
	Below 1"			8D	16	2D
Medium Tensile Steel	1 1/2" To 2"	17 1/2	33	4D	22	3D
	1" To 1 1/2"	18 1/2		4D	22	3D
	1/2" To 1"	19 1/2		8D	18	2D
	Below 1/2"	Do		8D	14	2D
High Tensile Steel	1 1/2" To 2"	21	37	4D	22	3D
	1" To 1 1/2"	22		4D	22	3D
	1/2" To 1"	23		8D	18	2D
	Below 1/2"	Do		8D	14	2D
Cold Drawn Wire	All Sizes	Not Speci- fied	37	8D	7 1/2	2D

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(c) *Twisted Bars.*

Material	Size D=Dia- meter In Inches	Minimum Stress Lbs./sq. in.		Elongation.		Diameter of Bend
		Yield	Ultimate	Length	% Age	
Twin Twisted Bars	Over 1"	54,000	63,000	5.7D	16	3D
	1" To 1"			5.7D	16	2D
	1" To 1"			11.3D	14	2D
	Below 1"			11.3D	12	2D
Twisted Square Bars	Over 1"	60,000	70,000	4.5D	16	4.2D
	1" To 1"	Do	Do	4.5D	16	2.8D
	1" To 1"	Do	Do	9D	14	2.8D
	Below 1"	70,000	80,000	9D	12	2.8D

D = Diameter of one round bar or side of square rod
before being twisted.

Istep Twisted Bars are mild steel bars treated by patent cold twisting and stretching process. The length after twisting is the same as original bars. Faulty rods break in the process of twisting, hence the rods which remain can stand higher stresses being without any defect. Yield point of these rods is at 54,000 lbs. per square inch. Bond stress of 540 lbs. per sq. inch and tensile stress of 27,000 lbs. per sq. inch can be permitted. Hooks, etc., which are required for anchorage can also be omitted and hence there is a saving of 33 per cent in weight of reinforcement.

(d) *Welded Fabrics (Plain and Twisted Steel).*—Several fabrics are available, names of a few being:

- | | |
|----------------------|----------------|
| 1. B.R.C. | 3. Matobar |
| 2. Maxweld | 4. Twist Steel |
| 5. Spun Groove, etc. | |

Manufacture of plain fabrics is controlled by B.S.S. 1221.

The fabric is to consist of main wires and cross-wire electrically welded.

The fabric is to be made of hard drawn steel wire complying with B.S.S. 785 and can be made both in oblong and square mesh. All joints and junctions are to be electrically welded.

MATERIALS

For twisted steel fabrics, cold twisted steel bars complying with B.S.S. 1144 are to be used. In case of oblong mesh, crossbars may be of plain hard-drawn steel wire complying with B.S.S. 785.

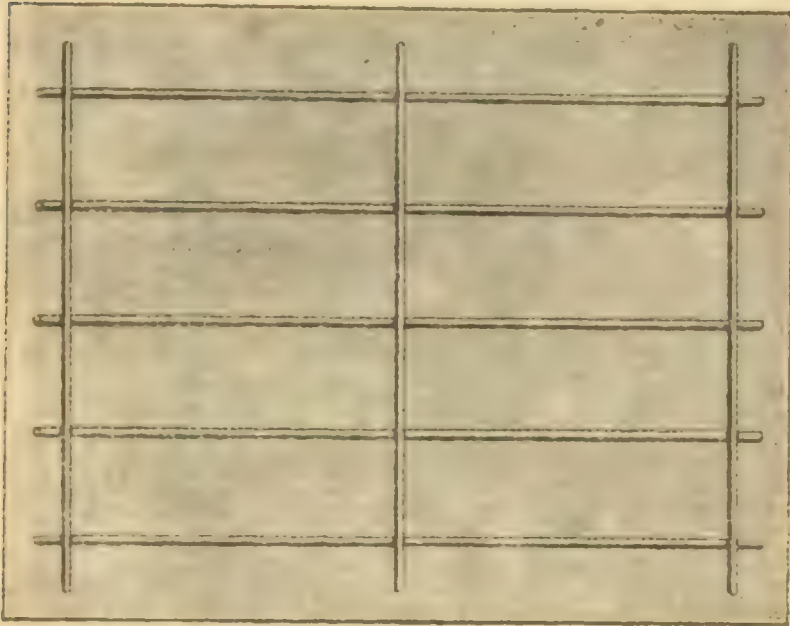


Fig. 1-7. B. R. C. Fabric.

- (i) *B.R.C. Fabric*: is made from hard-drawn steel wire and consists of a wire mesh made up of a series of parallel longitudinal wires held at fixed distances apart by means of transverse wires at right angles to longitudinal wires (See Fig. 1-7). A higher working tensile strength of 25,000 lbs. per sq. inch is recommended by the manufacturers. Properties of standard sizes of B.R.C. Fabric are given in the following table. The Fabric is available in sheets 7 ft. wide.

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Ref. No. of Fabric	Size of Mesh and or Wire					Weight Lbs./□ yd.
	Distance of Longi- tudinal Wires Inches	Distance of Cross Wires Inches	Gauge of Wire (Imperial)		Sectional Area Per Ft. Width Sq. In.	
			Longi- tudinal	Cross		
1	3	16	4/0	4	.5028	16.23
2	"	"	3/0	4	.4348	14.15
3	"	"	2/0	6	.3804	12.22
4	"	"	1/0	6	.3296	10.67
5	"	"	1	6	.2828	9.31
6	3	16	2	7	.2392	7.78
7	"	"	3	8	.1996	6.56
8	"	12	4	9	.1692	5.66
9	"	"	5	10	.1412	4.81
10	"	"	6	10	.1160	3.92
11	3	12	7	10	.0972	3.37
12	"	"	8	12	.0804	2.71
13	"	"	9	12	.0652	2.25
14	"	"	10	12	.0516	1.83
65	6	6	5	5	.0706	4.32
610	6	6	10	10	.0258	1.57

(ii) *Maxweld Fabrics*: These are also of the same type as B.R.C. and their references Nos. 403, 303, 203, 103, 1, 2, 3, 4, 5B, 6, 7, 8, 9, 10, 56 and 106 correspond approximately with Reference Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 65 and 610 of B.R.C. fabrics.

Fabrics Nos. 3, 4 and 5 are not very common in this country and hence particulars of the same have not been given.

(c) *Expanded Steel*: This is made from steel plates and sheets by cutting them and expanding them into diamond-shaped meshes of different sizes. Manufacture is controlled by B.S.S. 1221, Part C, main requirements being:

The blank steel plates shall have ultimate stress between 26 to 32 tons per sq. inch.

MATERIALS

The strength of the fabric shall be—

Minimum ultimate tensile stress 75,000 lbs. per sq. in.

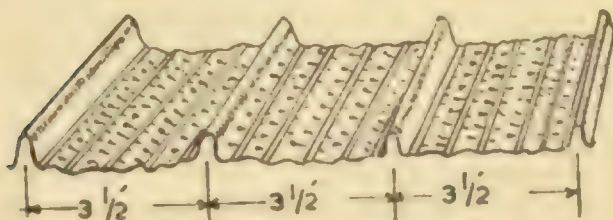
„ yield stress 50,000 „ „

„ elongation 7½%

Due to absence of any joints in the mesh work the fabric can be stressed to 20,000 lbs. per sq. inch in design work.

(f) *Ribbed Mesh Steel Sheets* (See Fig. 1-8) : The 'V' shaped ribs give rigidity to the fabrics and the meshwork is so shaped that it retains the wet concrete without appreciable loss of the same through the openings. Only timber joists are required for supporting the fabric at definite intervals depending upon the thickness of slab. This type of reinforcement is very convenient and economical in case of curved surfaces

'V'-SHAPED RIB



HY-RIB RIBBED MESH SHEET

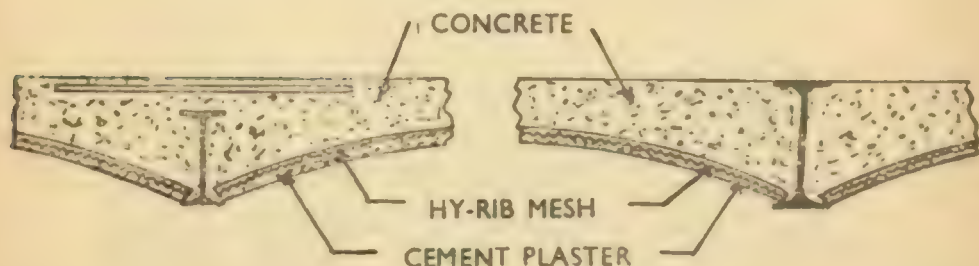


Fig. 1-8.

where shuttering cost is heavy (see Fig. 1-8). "Hyrib" and "Self-sentering" are two common trade names for such reinforcement available in this country in pre-war days.

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1.4.4 AREAS, WEIGHTS, ETC. OF BARS.

Round and Square M. S. Bars.

Weight in pounds per Lineal foot. Area in sq. inches and Perimeters in inches.

Dia- meter or Side in inches	Round ●				Square. ■			
	Weight	Area	Peri- meter	Lineal feet in 1 cwt.	Weight	Area	Peri- meter.	Lineal feet in 1 cwt.
3/16	.094	.027	.589	1102	.120	.035	.75	933
1/4	.167	.049	.785	667	.213	.062	1.00	526
5/16	.261	.076	.982	428	.332	.097	1.25	337
3/8	.376	.110	1.178	297	.478	.140	1.50	234
7/16	.511	.150	1.375	218	.651	.191	1.75	172
1/2	.669	.196	1.571	167	.840	.250	2.00	132
9/16	.845	.248	1.767	132	1.076	.316	2.25	104
5/8	1.043	.306	1.963	107	1.328	.399	2.50	84
11/16	1.262	.371	2.160	88	1.607	.472	2.75	70
3/4	1.502	.442	2.358	74	1.912	.562	3.00	59
12/16	1.703	.518	2.553	63	2.245	.660	3.25	50
7/8	2.044	.601	2.749	54	2.653	.765	3.50	43
15/16	2.347	.696	2.945	45	2.988	.879	3.75	37
1	2.670	.785	3.142	42	3.400	1.000	4.00	33
1 1/16	3.180	.904	3.534	33	4.343	1.265	4.50	26
1 1/8	4.172	1.227	3.927	27	5.312	1.562	5.00	22
1 1/4	5.049	1.485	4.320	22	6.428	1.820	5.50	17.5
1 1/2	6.008	1.767	4.713	18.5	6.650	2.250	6.00	15.6
2	10.68	3.141	6.283	10.5	13.60	4.000	8.00	8.2

Areas per foot width for various Spacings.

Spac- ing	Diameter of Bars.									
	3/16"	1/4"	5/16"	3/8"	7/16"	1/2"	5/8"	3/4"	7/8"	1"
4"	0.110	0.196	0.307	0.442	0.601	0.785	1.227	1.767	2.405	3.142
3 1/2"	0.095	0.162	0.263	0.379	0.515	0.673	1.052	1.515	2.06	2.69
4"	0.083	0.147	0.230	0.331	0.451	0.589	0.930	1.325	1.804	2.350
4 1/2"	0.074	0.131	0.205	0.295	0.401	0.524	0.818	1.178	1.604	2.09
5"	0.066	0.118	0.184	0.265	0.361	0.471	0.736	1.060	1.443	1.885
5 1/2"	0.060	0.107	0.167	0.241	0.328	0.428	0.669	0.964	1.312	1.714
6"	0.055	0.098	0.153	0.221	0.301	0.393	0.614	0.894	1.203	1.571
6 1/2"	0.051	0.091	0.142	0.204	0.278	0.365	0.566	0.816	1.110	1.450
7"	0.047	0.084	0.131	0.189	0.258	0.337	0.526	0.797	1.031	1.346
7 1/2"	0.044	0.079	0.123	0.177	0.241	0.314	0.491	0.707	0.962	1.257
8"	0.041	0.074	0.115	0.160	0.225	0.295	0.461	0.663	0.902	1.178
8 1/2"	0.039	0.069	0.108	0.150	0.212	0.277	0.433	0.624	0.849	1.109
9"	0.037	0.065	0.102	0.147	0.200	0.262	0.409	0.589	0.802	1.047
9 1/2"	0.035	0.062	0.097	0.140	0.190	0.248	0.368	0.526	0.760	0.992
10"	0.033	0.059	0.092	0.130	0.180	0.236	0.368	0.530	0.722	0.942
10 1/2"	0.032	0.056	0.088	0.126	0.172	0.224	0.351	0.505	0.687	0.899
11"	0.030	0.054	0.084	0.120	0.164	0.214	0.335	0.482	0.656	0.857
12"	0.028	0.049	0.077	0.110	0.150	0.196	0.307	0.442	0.591	0.785
13"	0.022	0.039	0.061	0.088	0.120	0.157	0.245	0.359	0.481	0.628
18"	0.018	0.030	0.051	0.074	0.100	0.131	0.205	0.295	0.401	0.524
24"	0.014	0.025	0.038	0.055	0.075	0.098	0.153	0.221	0.301	0.399

CHAPTER 2

PROPORTIONING OF CONCRETE

CONTENTS

- 2.1 Introduction and brief notes on some important terms pertaining to proportioning of concrete.
- 2.2 Essential requirements of concrete.
- 2.3 Proportioning of concrete.
 - 2.3.1 Arbitrary Method.
 - 2.3.2 Voids Method.
 - 2.3.3 Fineness Modulus Method.
 - 2.3.4 Grading Curves Method.
 - 2.3.5 Method of Trial Mixes.

CHAPTER 2

PROPORTIONING OF CONCRETE

2.1 INTRODUCTORY NOTES.

2.1.1 INTRODUCTION.

Concrete is a mixture of cement, water and aggregates, which consolidates into a hard mass due to chemical reaction between cement and water. Each of the four ingredients has its separate function. Coarse aggregates act as main filler. Fine aggregates fill in the voids in the coarse aggregates and cement and water form the binder. The science of proportioning of concrete is therefore mainly concentrated on the principle of obtaining a durable and strong concrete at the most economical rate. It is obvious that a properly designed concrete mix for certain requirements of strength should have the minimum possible cement content to make the mix economical.

2.1.2 WATER CEMENT RATIO.

The ratio of weight or volume of water used for mixing (correction of absorption by aggregates should be made), to weight or volume of cement in the concrete mixture. It may also be expressed as so many gallons of water per cwt. of cement. Since volume of cement is a variable term depending upon the manner in which a volumetric measure is filled, it is preferable always to express the water cement ratio on weight basis. Prof. D. Abrams discovered that the strength of concrete is solely governed by the amount of water used in making the concrete and is independent of the ratio of cement to aggregates provided the concrete is workable. The results of thousands of experiments carried out by him with various cement aggregate ratios are shown in Fig. 2-1 from which it will be noted that mixes varying from neat cement to 1:15 give the same strength. The equation of the curve is:—

$$S = \frac{A}{B^x} \text{ or } \log S = \log A - x \log B$$

S = compressive strength in lbs./sq. inch.

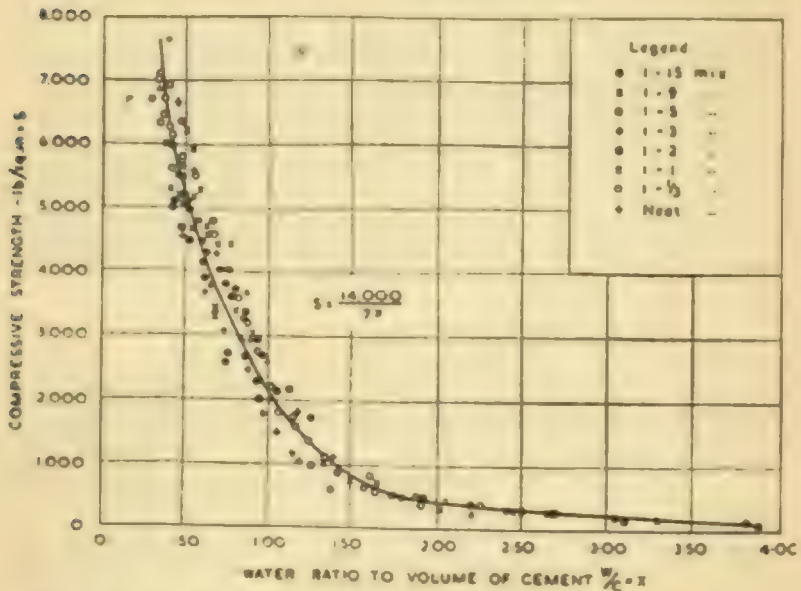
$$X = \frac{\text{Volume of mixing water}}{\text{Volume of cement}}$$

(Note.—1 cft. of cement is assumed to weigh 94 lbs.)

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A and B are constants depending upon age of concrete, quality of cement and aggregates, climatic conditions, mixing, etc.

For washed and graded gravel, workable mix mixed in a machine for one minute, the values of A and B are: $A=14000$ and $B=9$ for 28 days strength (for special control $B=7$).



Note: Lean and Rich Mixtures give same strength for same W/C Ratio. The figures represent Cylinder strengths which are $\frac{2}{3}$ the corresponding cube strengths.

Fig. 2-1.

It should be noted that though the water cement ratio law holds good universally the values of the constants A and B may vary according to the quality of cement, aggregates, etc. The values of compressive strength as given in curve in Fig. 2-1 are low, compared to present day values, as there is considerable progress in the manufacture of cement. The following values should therefore be used. Where the magnitude of the job permits the values of the constants should be found by actual experiments.

PROPORTIONING OF CONCRETE

Water Cement Ratio			Crushing Strength Lbs/□" @ 7 days	Remarks
Gals/cwt.	By Wt.	By volume		
4	.36	.52	5600	} mix too dry for hand com- paction
4½	.40	.58	4950	
5	.45	.64	4300	
5½	.49	.71	3750	
6	.54	.77	3250	} mix work- able for hand com- paction
6½	.58	.84	2850	
7	.63	.90	2400	
7½	.67	.97	2120	
8	.71	1.03	1850	} Wet mix
8½	.76	1.10	1670	
9	.80	1.16	1500	

(Note.—The figures are for cube test.)

2.13 WORKABILITY.

Has been defined in the simplest form as ease with which concrete can be mixed, handled, transported and placed. Workability will therefore vary according to the type of mould that is being used for the concrete structure under construction and the obstruction to the free flow of concrete caused by the spacing and nature of the reinforcement. Rational measure of workability is therefore not easy. A more scientific definition of workability would therefore be that property of concrete which determines the amount of useful internal work required to produce full compaction.

MEASUREMENT OF WORKABILITY.

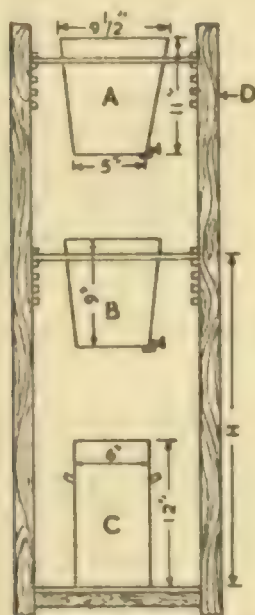
(a) *Slump Test* : is very widely used. Sometimes, however, accurate results are not possible by this test due to distorted slumps as shown in figure below. (Fig. 2-2.)



Fig. 2-2. Distorted Slump.

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(b) *Compacting Factor Test*.—It is a better test and depends on the definition of workability on basis of internal work as mentioned above. Concrete is made to fall into a mould from a standard height so that it compacts itself by gravity. Apparatus used is shown below. (Fig. 2-3.)



The height H determines the workability. The hopper (B) is not filled directly with concrete but by means of another hopper. (A). The heights of the hoppers can be varied as desired.

Fig. 2-3. Compaction Test.

- (A) Top Hopper (with hinged bottom).
- (B) Main " "
- (C) Mould.
- (D) Wooden Stand

2.2 ESSENTIAL REQUIREMENTS.

These are:—

- (a) Strength.
- (b) Durability.
- (c) Resistance to wear.
- (d) Water-tightness.
- (e) Compactness.
- (f) Workability.
- (g) Economy.

(a) *Strength*.—The capacity to withstand without injury the stresses developed when being used as a structural material.

PROPORTIONING OF CONCRETE

(b) *Durability*.—The property of resisting the action of chemical and physical destructive agents, such as—

- (i) Leaching due to lime contents in the cement being dissolved by pure and distilled waters.
- (ii) Expansion and contraction resulting from temperature and alternate drying and wetting.
- (iii) Freezing and thawing of water sucked in small crevices by capillary action.
- (iv) Disintegration by alkaline, acidic or saline waters.

(c) *Resistance to wear*.—Especially in case of pavements and roads.

(d) *Water-tightness*.—Obstructing through passage of water after initial absorption takes place.

(e) *Compactness*.—Is the proportion between the volume of concrete produced and the absolute volume of the aggregates and cement used.

(f) *Workability*.—Ease with which concrete can be handled, transported and placed.

(g) *Economy*.—Is effected by using local aggregates with minimum amount of cement and designing the mix properly to get the specified strength.

2.3 PROPORTIONING OF CONCRETE.

Various methods of proportioning are:—

2.3.1 ARBITRARY PROPORTIONS.

The proportions of cement, sand and coarse aggregates are specified as 1 : 2 : 4; 1 : 3 : 6, etc., mostly by volume.

2.3.2 SIMPLE VOIDS METHOD.

Voids in the coarse aggregates are to be filled in by the sand and voids in sand are to be filled in by cement paste. Ten per cent extra sand and 15 per cent extra cement paste are provided to allow for additional voids created by wedging action of sand particles on the coarse aggregates and that of cement particles on the sand.

Example.—Design a concrete mix if coarse aggregates and sand have 43% and 32% voids respectively.

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Sand required for 100 cft. of coarse aggregate
— $43+.43 \times 10$ —47.3 cft.

Cement paste required
— $(47.3 \times .32) + (47.3 \times .32 \times .15)$ —17.406 cft.

Dry cement required— 17.406×1.2 —20.9 cft.
—20.9 cft.

Proportions of cement : sand : coarse aggregate
— 20.9 : 47.3 : 100
— 1 : 2.31 : 4.9

2.3.3 FINENESS MODULUS METHOD.

2.3.3.1 Object.

The arbitrary mix method described earlier in para 2.3.1 has certain drawbacks, as the exact strength of the arbitrary mix is not known and such mixes are usually uneconomical. It is, therefore, necessary to specify concrete of a stipulated strength, and to work out an economical mix by some rational method. The following paras explain in a simple manner the convenient methods which may be adopted with advantage.

2.3.3.2 Variables in design of concrete mix.

The variables in the design of a mix are :

- (a) Water-cement ratio.
- (b) Cement content for a unit quantity of concrete.
- (c) Workability, grading of aggregates, and proportions of fine and coarse aggregates.

2.3.3.3 Data required for designing a concrete mix.

It is necessary to ascertain the following data before designing a satisfactory concrete mix.

The minimum compressive strength of concrete to which a structure is designed is essential, and the workability required is also necessary. As use has to be made of available aggregate, the grading of both coarse and fine aggregates, their weights, their bulking percentage and the water content must be known. These can be easily determined.

2.3.3.4 Relation between the minimum and average crushing strength.

Table 1 gives the estimated relation between the minimum and average crushing strength of works cubes for different conditions.

This serves as a guide for determining the average strength on which the mix design is to be based when the minimum strength is specified.

PROPORTIONING OF CONCRETE

2.3.3.5 Water-Cement Ratio.

Table 2 gives the relation between the crushing strength and water-cement ratio for fully compacted concrete using ordinary Portland cement. The water-cement ratio is determined for the average strength.

2.3.3.6 Workability and Slump.

The degrees of workability for various requirements are given in Table 3, and knowing the conditions of work, the required slump is determined from this table.

2.3.3.7 Weight of cement per 100 c.ft. of concrete.

The quantity of cement per 100 c.ft. of concrete may be determined from Table 4 in which the total quantity of water per 100 c.ft. of concrete is given. These values divided by the water-cement ratio give the required quantity of cement.

2.3.3.8 Absolute volumes of water, cement and mixed aggregates.

The quantity of water and of cement per 100 c.ft. of concrete being found, the absolute volumes of these two are obtained by dividing the weights by their absolute specific gravities. The absolute volume of mixed aggregate is then 100 minus absolute volumes of water and cement. The absolute specific gravities for cement, fine and coarse aggregates may be taken as 3.15, 2.65 and 2.55 respectively.

2.3.3.9 Determination of fineness moduli of fine and coarse aggregates and calculation of the proportions of fine and coarse aggregates.

The proportions of coarse and fine aggregates to produce optimum workability is obtained through Fineness Modulus. The fineness moduli of the coarse and of the fine aggregates are determined separately by ascertaining the percentage retained on each of the sieves.

$$100 - 52 - 25 - 14 - 7 = 3/16'' - 3/8'' - 1/2'' - 3/4'' - 3''$$

The sum of the percentages retained divided by 100 gives the F.M. Suitable F.M. for mixed aggregates are given in Table 5. The percentage of fine aggregate is obtained from $\frac{F_c - F_m}{F_c - F_f} \times 100$. Values of F_c and F_f i.e. the F.M. of coarse and fine aggregates respectively, are determined as above and the value of F_m , the F.M. for mixed aggregate, is taken from Table 5.

2.3.3.10 Absolute volumes and weights of fine and coarse aggregates.

Once the proportions of coarse and fine aggregates are determined as explained, the absolute volumes of these aggre-

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gates are obtained from these proportions. The weights of the aggregates are determined by multiplying the absolute volumes by absolute specific gravity and the weight of water.

2.3.3.11. Determination of the Nominal Mix.

The nominal mix is obtained by dividing the weights of the various components by the weight of cement.

2.3.3.12 Quantity of mixing water required.

In order to determine the quantity of mixing water required per 100 cft. of concrete, the free moisture in the aggregates has to be taken into account; the free moisture being obtained by multiplying the percentage of water in each aggregate by the weight required for 100 cft. of concrete. This free moisture is to be deducted from the total quantity of mixing water as determined in para 2.3.3.5.

2.3.3.13. Field Mix by Weight.

The field mix by weight is obtained by taking into consideration the free moisture in the aggregates in the nominal mix.

2.3.3.14. Field Mix by Volume.

It is often convenient to prepare a concrete mix by volume, and in such a case, bulking of the aggregates has to be taken into consideration. Bulking is the increase in volume of aggregates due to the presence of water. The method of correction for this item is shown in the example.

2.3.3.15 Quantity of mixing water required per bag of cement.

The mixing water required after allowing for the free moisture in the aggregates is easily obtained by dividing the mixing water as obtained in para 2.3.3.12 by the number of bags of cement required per 100 cft. of concrete as determined in para 2.3.3.7.

TABLE 1

Estimated relation between the Minimum and Average Crushing strengths of works cubes for different works conditions.

Conditions	Minimum strength as percentage of average strength.
Very good control with weight batching, constant supervision, etc.	75
Fair control	60
Poor Control	40

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TABLE 2

Relation between Cube Crushing Strength and Water-Cement Ratio by weight for Fully Compacted Concrete (Ordinary Portland Cement).

Water-cement ratio by weight	Cube crushing strength p.s.i.	
	7 days	28 days
0.35	5,700	7,500
0.40	5,000	6,700
0.45	4,300	6,000
0.50	3,600	5,300
0.55	3,100	4,600
0.60	2,600	4,000
0.65	2,200	3,500
0.70	1,900	3,100
0.75	1,600	2,800
0.80	1,500	2,500

NOTES: 1. Cylinder strength may be taken as 0.8 of cube strength.
 2. Strengths at 3 months and 1 year are approximately 25% and 67% greater than the strength at 28 days.

TABLE 3.

Degrees of workability for various requirements.

Degree of workability	Slump in inches	Use for which concrete is suitable.
"Very Low"	0 to 1	Vibrated concrete in roads or other large sections.
"Low"	1 to 2	Mass concrete foundation without vibration. Simple reinforced sections with vibration.
"Medium"	2 to 4	For normal reinforced work without vibration and heavily reinforced sections with vibration.
"High"	4 to 7	For sections with congested reinforcement. Not normally suitable for vibration.

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TABLE 4.

Water content per 100 cft. of concrete for 3" slump

Max. size of coarse aggregate	$\frac{1}{2}$ "	$\frac{3}{4}$ "	1"	1 $\frac{1}{2}$ "	2"	3"
Water in lbs.						
(a) for rounded coarse aggregate	1241	1149	1111	1037	982	926
(b) for angular coarse aggregate	1333	1241	1204	1122	1074	1019

For each 1" increase or decrease in slump, increase or decrease the water content by 3 percent.

TABLE 5.

Fineness Moduli of mixed aggregates for different sizes of aggregates.

Max. size of coarse aggregate.	$\frac{1}{2}$ "	$\frac{3}{4}$ "	1"	1 $\frac{1}{2}$ "	2"	3"
Fineness Moduli of mixed aggregate.						
Min.	4.5	4.8	5.0	5.4	5.7	5.9
Max.	5.0	5.3	5.5	6.0	6.3	6.5

EXAMPLE

(Paragraph numbers in this example are identical with the paragraph numbers in the text of section 2.3.3.)

3. Data

3.1 Minimum compressive strength—750 lbs. per sq. in.

3.2 Workability—Medium

3.3 Aggregates available

3.3.1 Coarse aggregates	$\frac{3}{4}$ " gravel (rounded coarse aggregate) with 40% passing $\frac{1}{2}$ " sieve.
Weight of C.A.	90 lbs. per cft.
Bulking percentage	2.56
Water content	1%

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3.3.2 Fine aggregates	% passing 100 sieve	2
	" 52 "	10
	" 25 "	45
	" 14 "	67
	" 7 "	87
	" 3/8 "	100
Weight of F. A.	100 lbs. per c. ft.	
Bulking percentage	14.3	
Water content	2 ⁰ / ₀	
3.4 Control	Fair	

$$4. \text{ Average crushing strength} = \frac{750 \times 3}{0.6} \text{ (Refer Table 1)}$$

$$= 3,750 \text{ p.s.i.}$$

Note :—Cube strength should be 3 times working strength.

$$5. \text{ Water-Cement Ratio} = 0.62 \quad \text{(Refer Table 2)}$$

$$6. \text{ Slump required} = 3'' \quad \text{(Refer Table 3)}$$

$$7. \text{ Determination of the weight of cement per 100 cft. of concrete.}$$

$$\begin{aligned} \text{Weight of cement per 100 cft. of concrete} &= \frac{\text{Total quantity of water per 100 cft. of concrete.}}{\text{Water-cement Ratio (Refer Table 4)}} \\ &= \frac{1149}{0.62} \\ &= 1853 \text{ lbs.} \end{aligned}$$

$$8. \text{ Absolute volumes of water, cement and mixed aggregates.}$$

$$8.1 \text{ Absolute volume of water} = \frac{1149}{62.4} = 18.4$$

$$8.2 \text{ Absolute volume of cement} = \frac{1853}{3.15 \times 62.4} = 9.4$$

$$\text{Absolute volume of water and cement} = 18.4 + 9.4 = 27.8 \text{ c.ft.}$$

$$8.3 \text{ Therefore, absolute volume of mixed aggregates} = 100 - 27.8 = 72.2 \text{ c.ft.}$$

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9. F.M. of fine and coarse aggregates and proportions of fine and coarse aggregates.

9.1 F.M. of coarse aggregates—F_c

<i>Sieve</i>	<i>Passing</i>	<i>Retained</i>
3/8"	40%	60%
3/4"	100%	0%
3/16"	0%	100%
7	0%	100%
14	0%	100%
25	0%	100%
52	0%	100%
100	0%	100%
		<hr/>
		660%
		<hr/>

$$F_c = \frac{660}{100} = 6.6$$

9.2 F.M. of fine aggregates = F_f

<i>Sieve</i>	<i>Passing</i>	<i>Retained</i>
100	2	98
52	10	90
25	45	55
14	67	33
7	87	13
3/16"	100	0
		<hr/>
		289
		<hr/>

$$F_f = \frac{289}{100} = 2.89$$

9.3 Average F.M. of mixed aggregates = 5.05 (Refer Table 5)

$$9.4 \text{ \% of fine aggregate} = \frac{F_o - F_m}{F_c - F_f} \times 100 = \frac{6.6 - 5.05}{6.6 - 2.89} \times 100 = 42$$

$$9.5 \text{ \% of coarse aggregate} = 100 - 42 = 58\%$$

10. Absolute volumes and weights of fine and coarse aggregates.

$$10.1 \text{ Absolute volume of fine aggregate} = 72.2 \times .42 = 30.3$$

$$10.2 \text{ Absolute volume of coarse} \quad \dots = 72.2 \times .58 = 41.9$$

$$10.3 \text{ Therefore, weight of fine aggregate per 100 c.ft. of concrete} = 30.3 \times 2.65 \times 62.4 = 5012 \text{ lbs.}$$

$$10.4 \text{ And weight of coarse aggregate per 100 c.ft. of concrete} = 41.9 \times 2.55 \times 62.4 = 6666 \text{ lbs.}$$

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11 Nominal Mix

$$\begin{array}{rcl} \text{Nominal mix} & = & \frac{1853}{1853} : \frac{5012}{1853} : \frac{6666}{1853} \\ & = & 1 : 2.7 : 3.6 \end{array}$$

12 Mixing water required per 100 c.ft. of concrete

$$\text{Water content of F.A.} = 5.12 \times .02 = 100 \text{ lbs.}$$

$$\text{Water content of C.A.} = 6666 \times .01 = 66 \text{ lbs.}$$

$$\text{Total water content of F.A. and C.A.} = 166 \text{ lbs.}$$

$$\text{Hence mixing water required} = 1149 - 166 = 983 \text{ lbs.}$$

$$= 98.3 \text{ gallons}$$

per 100 c.ft. of concrete after allowing for moisture in the aggregate.

13. Field Mix by Weight (taking into consideration weight of water in aggregates)

$$\begin{array}{rcl} & = & \frac{1853}{1853} : \frac{5012+100}{1853} : \frac{6666+66}{1853} \\ & = & 1 : 2.76 : 3.63 \end{array}$$

14. Field Mix by Volume (taking into consideration bulking of materials).

$$\text{Volume of cement in bags} = \frac{1853}{112} = 16.6 \text{ bags}$$

$$\begin{array}{l} \text{Volume of F.A.} \\ \text{allowing for} \\ \text{bulking} \end{array} = \frac{\text{weight of F.A. per} \\ \text{100 c.ft. of concrete.}}{\text{weight of F.A. per c.ft.}} (1 + \text{bulking per-} \\ \text{centage of F. A.})$$

$$\begin{array}{l} = \frac{5012}{100} \left(1 + \frac{14.3}{100} \right) \\ = 57.3 \text{ c.ft.} \end{array}$$

$$\begin{array}{l} \text{Volume of C.A.} \\ \text{after allowing} \\ \text{for bulking} \end{array} = \frac{\text{weight of C.A. per} \\ \text{100 c.ft. of concrete}}{\text{weight of C.A. per c.ft.}} (1 + \text{bulking per-} \\ \text{centage of C. A.})$$

$$\begin{array}{l} = \frac{6666}{90} \left(1 + \frac{2.56}{100} \right) \\ = 76 \text{ c.ft.} \end{array}$$

Field Mix by volume is therefore

$$\frac{16.6}{16.6} : \frac{57.3}{16.6} : \frac{76}{16.6}$$

$$1 \text{ bag cement} : 3.5 \text{ c.ft. sand} : 4.6 \text{ c.ft. coarse aggregate.}$$

15. Quantity of mixing water required per bag of cement after allowing for moisture in the aggregates

$$= \frac{98.3}{16.6} = 5.9 \text{ gallons}$$

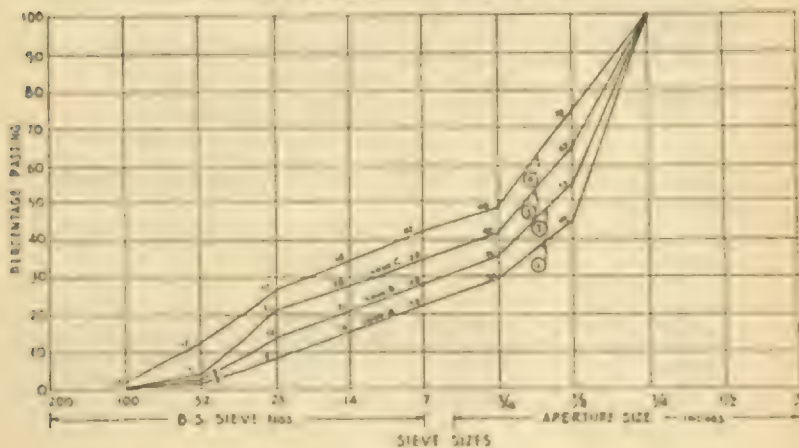
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2.3.4 GRADING CURVES METHOD OF PROPORTIONING.

2.3.4.1 In this method, the average crushing strength, water-cement ratio and the degree of workability are determined as in the previous method, use being made of Tables 1, 2 and 3.

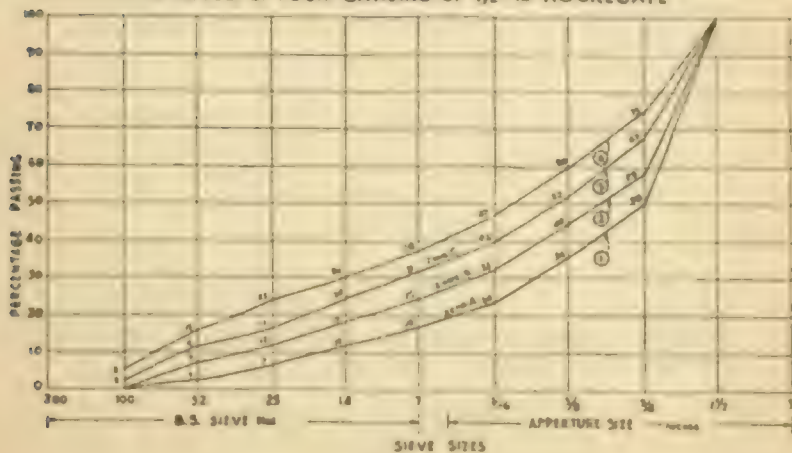
2.3.4.2 The aggregate-cement ratio is obtained from Table 6. These ratios are given for $\frac{3}{4}$ " and $1\frac{1}{2}$ " aggregates and for four different gradings in each case, as depicted in graphs Nos. A and B.

CURVES OF FOUR GRADINGS OF $\frac{3}{4}$ -in AGGREGATE



GRAPH A

CURVES OF FOUR GRADING OF $1\frac{1}{2}$ -in AGGREGATE



GRAPH B

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2.3.4.3 Suitable proportions of fine and coarse aggregates are determined from these graphs as illustrated in the second Example.

2.3.4.4 The nominal mix is read off from the results obtained in preceding para 2.3.4.3.

2.3.4.5 The field mix by weight is obtained by multiplying the nominal mix proportions by the weight of a bag of cement and adding the weight of free moisture.

2.3.4.6 The quantity of mixing water is obtained by multiplying the water-cement ratio by the weight of a bag of cement and deducting the free moisture in the aggregates.

2.3.4.7 The field mix by volume is obtained in the same way as in para 2.3.3.14.

The limitation of this method is that aggregate-cement ratio Tables are available for $\frac{3}{4}$ " and $1\frac{1}{2}$ " aggregates only at present.

Table 6 and graphs A and B are taken from the I. K. Road Research Institute Brochure No. 4 on "Design of Concrete Mixes", and Tables 1, 2 and 3 are based on data given in the same brochure.

TABLE NO. 6 Aggregate-Cement Ratio Required to give Four Degrees of Workability with different gradings and types of aggregate.

Degree of Workability	(A) $\frac{3}{4}$ in. Rounded Aggregate.															
	Very Low				Low				Medium				High			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
0.35	4.5	4.5	3.5	3.2	3.8	3.6	3.2	3.1	3.1	3.0	2.8	2.7	2.8	2.8	2.6	2.5
0.40	6.6	6.3	5.3	4.5	5.3	5.1	4.5	4.1	4.2	4.2	3.9	3.7	3.6	3.7	3.5	3.3
0.45	8.0	7.7	6.7	5.8	6.9	6.6	5.9	5.1	5.3	5.3	5.0	4.5	4.6	4.8	4.5	4.1
0.50			8.0	7.0	8.2	8.0	7.0	6.0	6.3	6.3	5.9	5.4	5.5	5.7	5.3	4.8
0.55				8.1			8.2	6.9	7.3	7.3	7.4	6.4	6.3	6.5	6.1	5.5
0.60								7.7			8.0	7.2		7.2	6.8	6.1
0.65								8.5				7.8				
0.70																
0.75																
0.80																
0.85																
0.90																
0.95																
1.00																

Water-cement ratio by weight

PROPORTIONING OF CONCRETE

TABLE NO. 6 (B) $\frac{1}{2}$ in. Irregular Gravel Aggregate.

Degree of Workability (Grading of aggregate (Curve No. on Graph A)	Very Low				Low				Medium				High			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
	3.7	3.7	3.5	3.0	3.0	3.0	3.0	2.7	2.6	2.6	2.7	2.4	2.4	2.5	2.5	2.2
0.35	4.8	4.7	4.7	4.0	3.9	3.9	3.8	3.5	3.3	3.4	3.5	3.2	3.1	3.2	3.2	2.9
0.40	6.0	5.8	5.7	5.0	4.8	4.8	4.6	4.3	4.0	4.1	4.2	3.9	3.9	3.9	3.9	3.5
0.45	7.2	6.8	6.5	5.9	5.5	5.5	5.4	5.0	4.6	4.8	4.8	4.5	4.4	4.4	4.4	4.1
0.50	8.3	7.8	7.3	6.7	6.2	6.2	6.0	5.7	5.4	5.4	5.4	5.1	4.8	4.9	4.9	4.7
0.55	9.4	8.6	8.0	7.4	6.8	6.9	6.7	6.2	6.0	6.0	6.0	5.6	5.4	5.4	5.2	5.2
0.60				8.0	7.4	7.5	7.3	6.8		6.4	6.4	6.1	6.2	6.1	6.1	6.1
0.65					8.0	8.0	7.7	7.4		7.2	7.2	7.0	6.6	6.6	6.5	7.0
0.70								7.9								7.4
0.75																7.7
0.80																8.0
0.85																
0.90																
0.95																
1.00																

Water-cement ratio by weight.

TABLE No. 6 (C) 1 in. Crushed Rock Aggregate.

Degree of Workability	Very Low				Low				Medium				High			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Grading of aggregate (Curve No. on Graph A)																
0.35	3.2	3.0	2.9	2.7	2.7	2.7	2.5	2.4	2.4	2.4	2.3	2.2	2.2	2.3	2.1	2.1
0.40	4.5	4.2	3.7	3.5	3.5	3.5	3.2	3.0	3.1	3.1	2.9	2.7	2.9	2.9	2.8	2.6
0.45	5.5	5.0	4.6	4.3	4.3	4.1	3.9	3.7	3.7	3.7	3.4	3.3	3.5	3.5	3.2	3.1
0.50	6.5	5.8	5.4	5.0	5.0	4.9	4.5	4.3	4.2	4.2	3.9	3.8		3.9	3.8	3.5
0.55	7.2	6.6	6.0	5.6	5.7	5.4	5.0	4.8	4.7	4.7	4.5	4.3			4.3	4.0
0.60	7.8	7.2	6.6	6.3	6.3	6.0	5.6	5.3		5.2	4.9	4.8			4.7	4.4
0.65	8.3	7.8	7.2	6.9	6.9	6.5	6.1	5.8		5.7	5.4	5.2			5.1	4.9
0.70	8.7	8.3	7.7	7.5	7.4	7.0	6.5	6.3		6.2	5.8	5.7			5.5	5.3
0.75			8.2	8.0	7.9	7.5	7.0	6.8			6.2	6.1			5.8	5.7
0.80							7.4	7.2			6.0	6.5			6.1	6.0
0.85								7.8			7.1	6.9			6.4	6.3
0.90											7.5	7.3				6.7
0.95											8.0	7.6				7.0
1.00																7.3

Water-cement ratio by weight.

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TABLE NO. 6 (D) 1½ in. Irregular River Gravel Aggregate.

Degree of Workability.	Very Low			Low			Medium			High		
	1	2	3	4	1	2	3	4	1	2	3	4
Grading of aggregate Curve No. on Graph B)	4.0	3.9	3.5	3.2	3.4	3.3	3.2	2.9	2.8	2.6	2.5	2.3
	5.3	5.3	4.7	4.3	4.5	4.5	4.2	3.8	3.8	3.7	3.5	3.1
	6.5	6.5	6.9	6.3	5.6	5.6	5.3	4.6	4.7	4.6	4.4	4.0
	7.7	7.7	7.1	6.8	6.7	6.6	6.3	5.4	5.7	5.5	5.2	4.8
		8.1		7.3	7.6	7.6	7.2	6.2	6.5	6.3	5.9	5.5
								7.4	7.0	7.1	6.7	6.2
								8.1	7.8	7.8	7.3	6.9
												7.4
												8.0
Water-cement ratio by weight.												

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EXAMPLE

(Paragraph numbers in this example are identical with the paragraph numbers in the text of section 2.3.4.)

2.3.4.1 Data.

Minimum compressive strength 750 lbs. per sq. in.

Workability—Medium.

Aggregates available :

Coarse aggregates $\frac{3}{4}$ " gravel (rounded coarse aggregate) with 40% passing $\frac{3}{4}$ " sieve.

Weight of C.A. 90 lbs. per cu. ft.

Bulking percentage 2.56

Water content 1%

Fine aggregates	% passing 100 sieve	2
	" 52 "	10
	" 25 "	45
	" 14 "	67
	" 7 "	87
	" $\frac{3}{4}$ "	100

Weight of F.A. 100 lbs. per cu. ft.

Bulking percentage 14.3

Water content 2%

Control Fair

Average crushing strength
$$= \frac{750 \times 3}{0.6} \text{ (Refer Table 1)}$$

 = 3,750 p.s.i

Note:—Cube strength should be 3 times working strength.

Water-cement Ratio —0.62 (Refer Table 2)

Slump required —3" (Refer Table 3)

2.3.4.2 Aggregate-Cement Ratio:

For a medium workability and w/c ratio of .62, two different aggregate-cement ratios are obtained from Table 6 as follows, irregular gravel being assumed:

For grading No. 3	....	6.2
" " No. 4	....	5.8

For an economic mix, the aggregate-cement ratio must be as high as possible, i.e., in this case, our grading should approximate to standard grading No. 3 (please refer to graph A).

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2.3.4.3 Proportions of Fine and Coarse Aggregates:

The following three trial mixes are prepared:

	Sand	Coarse Aggregate
A	30%	70%
B	35%	65%
C	40%	60%

The sieve analysis of these three mixes is determined and the results are as follows:—

		Percentage of material passing sieve		
B.S. Sieve		Sample containing 30% sand	Sample containing 35% sand	Sample containing 40% sand
No.	100	0.6	0.7	0.7
"	52	3.0	3.5	4.0
"	25	13.5	15.75	18.0
"	14	20.5	23.4	26.8
"	7	26.0	30.4	34.8
3/16	in.	30.0	36.0	40.0
3/8	in.	58.0	60.0	64.0
3/4	in.	100.0	100.0	100.0

Curves of these gradings are drawn on a tracing paper to the same scale as the optimum grading curves in graph A.

This tracing paper is superimposed on the optimum grading curves to ascertain which of the above three mixes approximates to optimum grading No. 3.

In this case, mix C approximates to optimum grading No. 3, hence, the mix containing 40% sand is suitable.

$$\text{Hence proportion of sand} = 6.2 \times \frac{40}{100} = 2.48$$

$$\text{and " of coarse aggregate} = 6.2 \times \frac{60}{100} = 3.72$$

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2.3.4.4 Nominal Mix.

Therefore the nominal mix = 1 : 2.48 : 3.72
say = 1 : 2.5 : 3.7

2.3.4.5 Field Mix by Weight.

The quantities of materials required by weight are:

Cement	—112 lbs.	
Sand	$2.5 \times 112 = 280$	.. plus weight of free moisture (.02 x 280 = 5.6) — 286 lbs.
Gravel	$3.7 \times 112 = 415$	.. plus weight of free moisture (.01 x 415 = 4.15) — 419 lbs.

The field mix by weight is therefore—

$$\frac{112}{112} : \frac{286}{112} : \frac{419}{112} \text{ i.e. } 1 : 2.55 : 3.74$$

2.3.4.6 Quantity of mixing water.

Water $0.62 \times 112 = 69.5$ —free moisture in sand and coarse
aggregate (9.75)
—59.25 lbs.
—say 6 gallons

2.3.4.7 Field Mix by Volume.

The quantities of materials required by volume are:

Cement	—1 bag
Sand	$\frac{280}{100} \times 1.143$ —3.2 cft.
Gravel	$\frac{419}{90} \times 1.0256$ —4.75 cft.

The field mix by volume is therefore 1 bag : 3.2 cft.
: 4.75 cft.

2.3.4.8 Remarks.

A slight variation in the mix from the results of the first example may be noted. This is due to the fact that the percentage of sand to gravel by the method of trial and error has been taken as 40 whereas in the first Example, the Fineness Modulus method gave a percentage of 42.

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2.3.5 THE METHOD OF TRIAL MIXES.

(Portland Cement Association, U.S.A.)

In this method also laboratory data on trial concrete mixes made with varying sizes and proportions of aggregates and water content are made use of, in arriving at the proper type of mix for a particular job. Various steps followed in this method are:—

- (a) Selection of w/c ratio to get the strength and durability desired.
- (b) Selection of slump for desired workability and maximum size of aggregates to be used.
- (c) Selection of approximate trial mix for the particular type of aggregates to be used on the job. The total water content and sand to coarse aggregate ratio of this trial mix is used and the exact trial mix for the given aggregates is calculated. If the aggregates as supplied in the field are wet, correction for moisture is made.

(a) W/C RATIOS FOR VARIOUS TYPES OF CONSTRUCTION OR EXPOSURE CONDITIONS

Type or Location of Structure	Severe or Moderate Climate Wide Range of Temperature Hail & Long Freezing Spells					Mild Climate				
	Thin Section		Moderate Section		Heavy Section Mass Concrete	Thin Section		Moderate Section		Heavy Section Mass Concrete
	R.C.C.	Plain	R.C.C.	Plain		R.C.C.	Plain	R.C.C.	Plain	
At the Water Line in Hydraulic Structures Subject to Intermittent Saturation										
In Sea Water	.44	.49	.49	.53	.53	.44	.49	.49	.53	.53
In Fresh Water	.49	.53	.53	.58	.58	.49	.53	.53	.58	.58
Hydraulic Structures away from Water Line but subject to frequent wetting										
By Sea Water	.49	.53	.53	.58	.58	.49	.53	.53	.58	.58
By Fresh Water	.53	.58	.58	.63	.63	.53	.58	.58	.63	.63
Ordinary exposed Structures, Buildings, etc.	.53	.58	.58	.63	.63	.53	.58	.58	.63	.63
Submerged Structures										
In Sea Water	.53	.58	.58	.63	.63	.53	.58	.58	.63	.63
In Fresh Water	.58	.63	.63	.68	.68	.58	.63	.63	.68	.68
Pavement Slabs										
Wearing Slabs	.49	.53				.53	.58			
Base Slabs	.53	.58				.58	.63			

CONCRETE ENGINEERS' HANDBOOK

Curves for selecting w/c ratio for particular strength.
(Portland Cement Association's figures.)

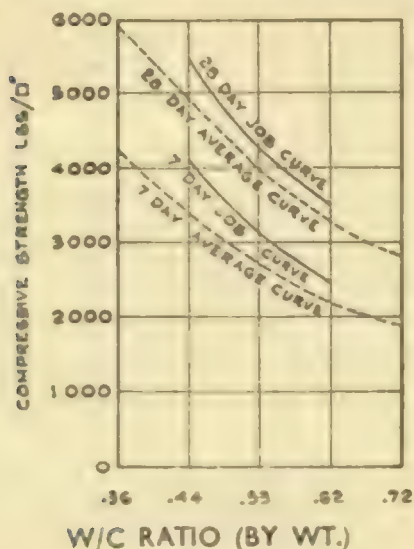


Fig. 2-4.

Results of experiments by Indian Railways for
compressive strength of Indian cements (Standard Cylinders).

W/c Ratio By wt.	.33	.45	.55	.66	.78	.89
Min. Compressive Strength @ 7 days lbs./sq. in.	2900	2420	1980	1580	1200	920
Average Comp. Strength @ 7 days lbs./sq. in.	3500	3000	2550	2150	1780	1500
Average Comp. Strength @ 28 days taken as 150% Strength @ 7 days	5250	4500	3825	3225	2670	2250

It will be noted that there is slight difference in the figure in the above two as well as those in table in paragraph 2.3.3. Hence the w/c ratio should be selected by judgment for small jobs and for important big jobs actual tests should be made and curves plotted accordingly.

PROPORTIONING OF CONCRETE

(b) *Slump for particular job*:—To be selected according to nature of work. Maximum size of aggregates to be used will depend on nature of work and should be as per following table:—

Minimum dimension of section in inches	Max. Size of aggregate in inches			
	R.C. walls beams & cols.	Unrein- forced walls	Heavily reinforced Slabs.	Lightly reinforced Slabs.
2½ to 5	½ to ¾	¾	¾ to 1	¾ to 1½
6 to 11	¾ to 1½	1½	1½	1½ to 3
12 to 29	1½ to 3	3	1½ to 3	3
30 or more	1½ to 3	6	3	3 to 6

(c) *Typical Trial Mixes*.—These are given for medium consistency concrete made with coarse, medium and fine sand and rounded or angular coarse aggregate varying from ¾" maximum size to 2" maximum size. In calculating the quantities of materials it is necessary to use the principle of absolute volume. It is assumed that in, say, 1 cubic yard of compact concrete water occupies all the voids in cement powder. The cement-water paste occupies all the voids in the sand and cement paste and sand mortar in their turn occupy all the voids in the coarse aggregate. Thus the volume of concrete produced by any combination of materials equals the sum of absolute volume of cement and aggregates and the volume of water. The absolute volume of a loose material is the actual total volume of solid matter in all the loose particles and is obtained as follows:—

$$\text{Absolute volume} = \frac{\text{Wt. of loose material}}{\text{Sp. gravity} \times \text{unit wt. of water}}$$

Specific gravities of materials used in concrete are:—

Cement 3.15; Sand 2.65; Gravel 2.65; Trap 2.90; Granite 2.70; Hard Stone 2.55; Lime Stone 2.65; and Water 1.0.

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SUGGESTED TRIAL MIXES FOR CONCRETE OF MEDIUM CONSISTENCY.

(Slump=3")

FINE SAND. (F.M. 2.2 to 2.6) *Rounded Coarse Aggregates.*

Max. Size of C.A.	Water Gals./Cwt of Cement.	Sand %age of Total	Per Cwt. of Cement		Per Cubic Yard of Concrete				Yield Cubic ft. per Cwt of Cement.
			Sand	Gravel	Water	Cement.	Sand	Gravel	
3	5	41	200	290	310	6.2	1260	1900	4.35
1	5	36	185	325	300	6.1	1115	1980	4.45
1½	5	32	178	380	280	5.7	1020	2190	4.72
2	5	29	178	430	270	5.4	960	2300	5.05
3	5½	42	230	320	310	5.6	1310	1810	4.8
1	5½	37	215	362	300	5.4	1170	1985	4.95
1½	5½	33	203	415	280	5.2	1055	2170	5.20
2	5½	30	203	475	270	4.85	985	2320	5.60
3	6	43	263	345	310	5.2	1360	1800	5.20
1	6	38	245	394	300	5.0	1230	1980	5.35
1½	6	34	232	451	280	4.8	1110	2165	5.65
2	6	31	232	520	270	4.45	1035	2300	6.10
3	6½	44	292	375	310	4.8	1400	1795	5.65
1	6½	39	275	430	300	4.65	1265	1980	5.85
1½	6½	35	267	495	280	4.38	1170	2160	6.19
2	6½	32	262	560	270	4.10	1080	2300	6.60
3	7	45	327	400	310	4.45	1460	1775	6.1
1	7	40	304	460	300	4.30	1300	1965	6.3
1½	7	36	292	520	280	4.1	1200	2130	6.5
2	7	33	292	590	270	3.85	1125	2275	7.0
3	7½	46	361	430	310	4.1	1495	1765	6.6
1	7½	41	332	482	300	4.0	1345	1945	6.7
1½	7½	37	328	560	280	3.8	1240	2115	7.2
2	7½	34	322	625	270	3.6	1160	2260	7.5
3	8	47	400	334	310	3.85	1540	1750	7.0
1	8	42	370	512	300	3.8	1395	1935	7.2
1½	8	38	357	585	280	3.6	1290	2105	7.5
2	8	38	357	670	270	3.85	1200	2240	8.1

PROPORTIONING OF CONCRETE

II FINE SAND (F.M. 22 to 26) Angular Coarse Aggregates

Max. Size of C.A.	Water Gals. Cwt of Cement.	Sand %age of Total	Per Cwt. of Cement		Per Cubic Yard of Concrete				Yield c.ft. per Cwt. of Cement.
			Sand	Stone	Water	Cement.	Sand	Stone	
$\frac{1}{2}$	5	46	202	238	335	6.73	1360	1600	4.02
1	5	41	185	208	325	6.55	1210	1755	4.12
$1\frac{1}{2}$	5	37	185	310	305	6.22	1150	1925	4.35
2	5	34	185	352	295	5.98	1085	2065	4.60
$\frac{1}{2}$	$5\frac{1}{2}$	47	232	262	335	6.13	1420	1605	4.40
1	$5\frac{1}{2}$	42	214	296	325	5.96	1280	1775	4.52
$1\frac{1}{2}$	$5\frac{1}{2}$	38	208	345	300	5.62	1170	1945	4.80
2	$5\frac{1}{2}$	35	208	387	295	5.37	1120	2080	5.02
$\frac{1}{2}$	6	48	262	280	335	5.62	1475	1575	4.8
1	6	43	244	321	325	5.46	1330	1755	4.95
$1\frac{1}{2}$	6	39	238	369	300	5.20	1240	1920	5.20
2	6	36	238	424	295	4.87	1160	2060	5.55
$\frac{1}{2}$	$6\frac{1}{2}$	49	298	304	335	5.2	1520	1580	5.20
1	$6\frac{1}{2}$	44	274	345	325	5.04	1380	1740	5.35
$1\frac{1}{2}$	$6\frac{1}{2}$	40	268	400	300	4.78	1280	1910	5.65
2	$6\frac{1}{2}$	37	268	452	295	4.53	1215	2050	5.95
$\frac{1}{2}$	7	50	327	327	335	4.78	1570	1570	5.65
1	7	45	304	369	325	4.70	1430	1735	5.75
$1\frac{1}{2}$	7	41	298	428	300	4.45	1325	1910	6.05
2	7	38	298	476	295	4.20	1250	2050	6.42
$\frac{1}{2}$	$7\frac{1}{2}$	51	363	345	335	4.45	1615	1540	6.05
1	$7\frac{1}{2}$	46	333	393	325	4.36	1460	1715	6.15
$1\frac{1}{2}$	$7\frac{1}{2}$	42	333	458	300	4.12	1370	1890	6.60
2	$7\frac{1}{2}$	39	327	512	295	3.95	1290	2020	6.85
$\frac{1}{2}$	8	52	393	365	335	4.20	1650	1525	6.42
1	8	47	369	417	325	4.12	1520	1715	6.60
$1\frac{1}{2}$	8	43	363	482	300	3.86	1405	1865	7.00
2	8	40	363	542	295	3.69	1340	2000	7.32

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10 MEDIUM SAND (F.M. 26 to 29) *Rounded Coarse Aggregates.*

Max. Size of C.A.	Water Gals/ Cwt. of Cement.	Sand %age of Total	Per Cwt. of Cement.		Per Cubic Yard of Concrete.				Yield C. ft. per Cwt. of Cement.
			Sand Lbs.	Gravel Lbs.	Water Lbs.	Cement Cwts.	Sand Lbs.	Gravel Lbs.	
$\frac{3}{4}$	5	43	214	280	310	6.2	1330	1720	4.35
1	5	38	190	321	300	6.1	1190	1645	4.45
1 $\frac{1}{2}$	5	34	190	369	280	5.7	1090	2110	4.72
2	5	31	190	417	270	5.4	1025	2240	5.05
$\frac{3}{4}$	5 $\frac{1}{2}$	44	244	310	310	5.6	1370	1740	4.80
1	5 $\frac{1}{2}$	39	226	357	300	5.4	1235	1950	4.95
1 $\frac{1}{2}$	5 $\frac{1}{2}$	35	214	405	280	5.2	1115	2115	5.20
2	5 $\frac{1}{2}$	32	214	464	270	4.9	1045	2260	5.60
$\frac{3}{4}$	6	45	274	338	310	5.2	1425	1735	5.20
1	6	40	256	381	300	5.0	1290	1920	5.35
1 $\frac{1}{2}$	6	36	244	434	280	4.8	1170	2080	5.65
2	6	33	250	506	270	4.45	1110	2250	6.10
$\frac{3}{4}$	6 $\frac{1}{2}$	46	310	363	310	4.8	1480	1740	5.65
1	6 $\frac{1}{2}$	41	292	417	300	4.65	1320	1925	5.85
1 $\frac{1}{2}$	6 $\frac{1}{2}$	37	280	476	280	4.38	1220	2080	6.19
2	6 $\frac{1}{2}$	34	280	542	270	4.10	1150	2230	6.60
$\frac{3}{4}$	7	47	339	387	310	4.45	1510	1725	6.1
1	7	42	321	440	300	4.30	1375	1890	6.3
1 $\frac{1}{2}$	7	38	310	500	280	4.10	1275	2060	6.5
2	7	35	310	572	270	3.85	1195	2210	7.0
$\frac{3}{4}$	7 $\frac{1}{2}$	48	381	417	310	4.1	1570	1715	6.6
1	7 $\frac{1}{2}$	43	352	464	300	4.0	1415	1875	6.7
1 $\frac{1}{2}$	7 $\frac{1}{2}$	39	345	542	280	3.75	1305	2050	7.2
2	7 $\frac{1}{2}$	36	339	607	270	3.6	1225	2190	7.5
$\frac{3}{4}$	8	49	418	434	310	3.85	1610	1685	7.0
1	8	44	387	494	300	3.8	1465	1870	7.2
1 $\frac{1}{2}$	8	40	374	560	280	3.6	1355	2020	7.5
2	8	37	381	643	270	3.85	1280	2160	8.1

PROPORTIONING OF CONCRETE

IV. MEDIUM SAND (F. M. 2.6 to 2.9) Angular Coarse Aggregates.

Max. Size of C.A.	Water Gals/ Cwt of Cement.	Sand %age of Total	Per Cwt. of Cement.		Per Cubic Yard of Concrete.				Yield C. ft. per Cwt of Cement.
			Sand	Stone	Water	Cement.	Sand	Stone	
1	5	48	208	226	335	6.73	1400	1526	4.02
1	5	43	196	262	325	6.55	1290	1715	4.12
1½	5	39	190	298	305	6.22	1185	1850	4.35
2	5	36	190	345	295	5.98	1120	2030	4.60
1	5½	49	238	250	335	6.13	1460	1535	4.40
1	5½	44	226	286	325	5.96	1350	1705	4.52
1½	5½	40	333	333	305	5.62	1240	1875	4.80
2	5½	37	375	375	295	5.37	1185	2015	5.02
1	6	50	274	274	335	5.02	1540	1540	4.8
1	6	45	256	310	325	5.46	1400	1690	4.95
1½	6	41	250	357	305	5.20	1300	1860	5.20
2	6	38	250	411	295	4.87	1220	2000	5.55
1	6½	51	394	292	335	5.20	1580	1520	5.20
1	6½	46	286	333	325	5.04	1440	1680	5.35
1½	6½	42	280	387	305	4.78	1340	1850	5.65
2	6½	39	280	440	295	4.53	1270	2000	5.95
1	7	52	339	316	335	4.78	1625	1510	5.65
1	7	47	316	357	325	4.70	1480	1680	5.75
1½	7	43	310	417	305	4.45	1380	1855	6.05
2	7	40	316	470	295	4.20	1325	1975	6.42
1	7½	53	375	333	335	4.45	1670	1485	6.05
1	7½	48	352	381	325	4.36	1535	1665	6.15
1½	7½	44	352	440	305	4.12	1445	1810	6.60
2	7½	41	345	494	295	3.95	1360	1950	6.85
1	8	54	411	345	335	4.20	1725	1540	6.42
1	8	49	381	400	325	4.12	1570	1640	6.60
1½	8	45	381	470	305	3.86	1470	1820	7.00
2	8	42	381	524	295	3.69	1410	1935	7.32

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V COARSE SAND (F.M. 2.9 to 3.2) *Rounded Coarse Aggregates*

Max. Size of C.A.	Water Gals./Cwt. of Cement	Sand %age of Total	Per Cwt. of Cement		Per Cubic Yard of Concrete				Yield C. ft. per Cwt. of Cement
			Sand	Stone	Water	Cement	Sand	Stone	
			Lbs.	Lbs.	Lbs.	Cwts.	Lbs.	Lbs.	
$\frac{1}{8}$	5	45	220	274	310	6.4	1370	1700	4.35
1	5	40	208	310	300	6.1	1260	1870	4.45
$1\frac{1}{2}$	5	36	202	357	280	5.7	1155	2040	4.72
2	5	33	202	405	270	5.4	1090	2175	5.05
$\frac{1}{8}$	5 $\frac{1}{2}$	40	256	298	310	5.6	1440	1675	4.80
1	5 $\frac{1}{2}$	41	238	339	300	5.4	1300	1855	4.95
$1\frac{1}{2}$	5 $\frac{1}{2}$	37	226	393	280	5.2	1180	2045	5.20
2	5 $\frac{1}{2}$	34	232	446	270	4.9	1130	2175	5.60
$\frac{1}{8}$	6	47	286	321	310	5.2	1490	1675	5.20
1	6	42	268	369	300	5.0	1350	1860	5.35
$1\frac{1}{2}$	6	38	262	424	280	4.8	1250	2020	5.65
2	6	35	262	488	270	4.45	1165	2170	6.10
$\frac{1}{8}$	6 $\frac{1}{2}$	48	321	345	310	4.8	1540	1650	5.65
1	6 $\frac{1}{2}$	43	304	400	300	4.65	1400	1840	5.85
$1\frac{1}{2}$	6 $\frac{1}{2}$	39	298	464	280	4.38	1300	2030	6.15
2	6 $\frac{1}{2}$	36	298	524	270	4.10	1225	2160	6.60
$\frac{1}{8}$	7	40	357	369	310	4.45	1590	1640	6.1
1	7	44	333	428	300	4.30	1430	1835	6.3
$1\frac{1}{2}$	7	40	321	482	280	3.10	1320	1985	6.5
2	7	37	321	554	270	3.85	1240	2140	7.0
$\frac{1}{8}$	7 $\frac{1}{2}$	50	400	400	310	4.1	1640	1640	6.6
1	7 $\frac{1}{2}$	45	369	446	300	4.0	1490	1800	6.7
$1\frac{1}{2}$	7 $\frac{1}{2}$	41	363	524	280	3.75	1375	1980	7.2
2	7 $\frac{1}{2}$	38	357	590	270	3.60	1290	2130	7.5
$\frac{1}{8}$	8	51	435	417	310	3.85	1680	1610	7.0
1	8	46	405	476	300	3.80	1530	1800	7.2
$1\frac{1}{2}$	8	42	393	542	280	3.60	1420	1960	7.5
2	8	39	400	625	270	3.85	1340	2100	8.1

PROPORTIONING OF CONCRETE

VI COARSE SAND (F.M. 2.9 to 3.2) Angular Course Aggregates.

Max. Size of C.A.	Water Gals/ Cwt. of Cement.	Sand %age of Total	Per Cwt. of Cement.		Per Cubic Yard of Concrete.				Yield C. ft. per Cwt. of Cement.
			Sand Lbs.	Stone Lbs.	Water Lbs.	Cement Cwts.	Sand Lbs.	Stone Lbs.	
1	5	50	220	220	335	6.73	1480	1480	4.02
1	5	45	202	250	325	6.55	1325	1640	4.12
1½	5	41	203	290	305	6.22	1260	1810	4.35
2	5	38	199	328	295	5.98	1190	1960	4.60
1	5½	51	250	238	335	6.13	1535	1460	4.40
1	5½	46	232	275	325	5.96	1385	1635	4.52
1½	5½	42	232	322	305	5.62	1310	1810	4.80
2	5½	39	232	364	295	5.37	1250	1950	5.02
1	6	52	280	262	335	5.62	1575	1475	4.8
1	6	47	268	296	325	5.46	1460	1625	4.95
1½	6	43	262	346	305	5.20	1360	1800	5.20
2	6	40	263	398	295	4.87	1280	1940	5.55
1	6½	53	316	280	335	5.20	1640	1400	5.20
1	6½	48	290	322	325	5.04	1500	1620	5.35
1½	6½	44	294	365	305	4.78	1400	1795	5.65
2	6½	41	298	430	295	4.53	1350	1920	5.95
1	7	54	350	296	335	4.78	1680	1425	5.65
1	7	49	328	346	325	4.70	1540	1625	5.75
1½	7	45	327	398	305	4.45	1455	1775	6.05
2	7	42	330	452	295	4.20	1400	1900	6.42
1	7½	55	394	322	335	4.45	1750	1430	6.05
1	7½	50	329	320	325	4.36	1585	1585	6.15
1½	7½	46	366	430	305	4.12	1520	1765	6.60
2	7½	43	362	475	295	3.95	1430	1880	6.85
1	8	56	423	384	335	4.20	1775	1400	6.42
1	8	51	398	380	325	4.12	1640	1570	6.60
1½	8	47	400	452	305	3.86	1540	1750	7.00
2	8	44	400	506	295	3.69	1475	1870	7.32

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Note.—The preceding tables apply to concrete of 3 inches slump and made with natural sand. For concrete with different slump and made with stone sand the following adjustment should be made before using the tables:—

- (1) Increase or decrease water content by 3% for each increase or decrease of 1 inch in slump.
- (2) For stone sand increase percentage of sand by about 3 and water content by about 15 lbs. per cubic yard of concrete. For less workable concrete as in pavements decrease percentage of sand by about 3 and water content by 8 lbs. per cubic yard of concrete.

An illustrative example will make the procedure clear. A reinforced concrete structure of thin section is to be exposed to fresh water in a severe climate where freezing and thawing takes place. The strength of concrete required is 3,750 lbs./sq. in. The C. Aggregate to be used is gravel $1\frac{1}{2}$ " downwards carrying free moisture of 1%. The fine aggregate consists of natural sand of f.m. 2.5 with free moisture of 3%. The specific gravities of both are 2.65. The slump required for the concrete is 4".

W/c ratio from table on page 47—49, i.e., say $5\frac{1}{2}$ gals./cwt.

Do. graph on page 48—55

Take the lower figure of .49.

Approximate trial mix from page 50 is

1 cwt. of cement: 203 lbs. of sand: 415 lbs. of gravel.

The percentage of sand will be about 33 and 280 lbs. of water will be required per cubic yard of concrete.

From these assumptions we shall find out the correct trial mix for 4" slump since the table gives figures for 3" slump.

Water required for 4" slump = $1.03 \times 28.0 = 29.0$ gallons

Cement required per cubic yard of concrete

$$\frac{29.0}{5.5} = 5.3 \text{ cwts say } 5.4 \text{ bags}$$

% age of sand given in the table is 33

$$\text{absolute volume of Cement} = \frac{5.4 \times 110}{3.15 \times 62.3} = 3.07 \text{ cft.}$$

$$\text{volume of water required} = \frac{29.0}{6.25} = 4.70 \text{ cft.}$$

$$\therefore \text{volume of Cement paste} = 7.77 \text{ cft}$$

$$\therefore \text{absolute volume of aggregates} = 27 - 7.77 = 19.23 \text{ cft.}$$

$$\therefore \text{absolute volume of sand} = .33 \times 19.23 = 6.35 \text{ cft.}$$

$$\therefore \text{wt. of surface dry sand} = 6.35 \times 2.65 \times 62.3 = 1048 \text{ lbs.}$$

$$\& \text{ absolute volume of gravel} = .67 \times 19.23 = 12.90 \text{ cft.}$$

$$\therefore \text{weight of surface dry gravel} = 12.90 \times 2.65 \times 62.3 = 2130 \text{ lbs.}$$

and so for each bag of cement (110 lbs.)

PROPORTIONING OF CONCRETE

we require, $\frac{1048}{5.4} = 195$ lbs. of sand and

$$\frac{2130}{5.4} = 394 \text{ lbs. of gravel}$$

Since the sand and gravel are wet we must take

$$195 + \frac{3}{100} \times 195 = 195 + 6 = 201 \text{ lbs. of wet sand}$$

$$\text{and } 394 + \frac{1}{100} \times 394 = 394 + 4 = 398 \text{ lbs. of wet gravel}$$

The water to be added to

$$\text{the mix will be } 5.5 - \frac{6+4}{10} \text{ gallons}$$

$$= 4.5 \text{ gallons.}$$

corrected field mix for trial is

1 bag of cement (110 lbs. net)

201 lbs. of sand

398 lbs. of gravel and

4.50 gallons of water.

CHAPTER 3

LOADS, BENDING MOMENTS AND SHEARING FORCES

CONTENTS

3.1 Dead Loads.

(i) Weights of Materials.

- (a) Bituminous substances.
- (b) Excavated materials.
- (c) Liquids.
- (d) Minerals and building stones.
- (e) Metals.
- (f) Timber.
- (g) Solids (miscellaneous).
- (h) Stored materials.

(ii) Weights of structural items.

3.2 Live Loads.

3.3 Formulæ for Bending Moments and Shearing Forces.

3.4 Bending Moments for r.c.c. slabs (ready calculated) Table & Chart

3.5 Bending Moments for Beams (ready calculated) Table & Chart

CHAPTER 3 LOADS, BENDING MOMENTS AND SHEARING FORCES

3.1 DEAD LOADS.

(i) Weights of Materials :

(a) Bituminous substances :

	lbs./c.ft.
Asphaltum	81
Coal anthracite	97
" bituminous	84
" lignite	78
" peat	47
" charcoal light	23
" " heavy	33
" coke	75
Graphite	31
Paraffin	56
Petroleum (crude)	55
" (refined)	50
Pitch	69
Tar bituminous	75

(b) Excavated Materials :

	lbs./c.ft.
Clay dry	63
" damp plastic	110
Clay & gravel dry	110
Earth dry loose	76
" " packed	95
" moist loose	78
" " packed	96
" mud flowing	108
" " packed	115
Riprap	80 to 90
Sand gravel dry loose	90 to 105
" packed	100 to 120
" wet	118 to 120

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(c) Liquids:

			lbs./c.ft.
Alcohol	49
Acids muriatic	75
" nitric	94
" sulphuric	112
Oils vegetable	58
" mineral	..	..	57
Petroleum	..	..	55
Gasoline	..	..	42
Water fresh	..	..	62.4
" sea	..	..	64.0
Ice	..	..	57

(d) Minerals & Building Stones:

Asbestos	..	..	153
Barytes	..	..	281
Basalt	..	..	184
Bauxite	..	..	159
Chalk	..	..	137
Clay marl	..	..	137
Copper ore (pyrites)	..	..	262
Dolomite	..	..	181
Granite	..	..	175
Hematite	..	..	325
Gypsum	..	..	159
Hornblende	..	..	187
Limestone marble	..	..	165
Lead ore (galena)	..	..	465
Magnesite	..	..	187
Porphyry	..	..	172
Pumice	..	..	40
Quartz	..	..	165
Sandstone	..	..	175
Soapstone	..	..	169
Lime (ore)	..	..	253
Cement	..	..	90

(e) Metals:

Aluminium	..	..	165
Brass	..	..	534
Bronze	..	..	509
Chromium	..	..	428
Copper	..	..	556
Gold	..	..	1205

LOADS, BENDING MOMENTS AND SHEARING FORCES

				lbs./c.ft.
Iron (pig)	..	..	..	450
" (wrought)	..	..	..	485
" (steel)	..	..	..	490
Lead ..	..	..	..	706
Magnesium	..	..	..	109
Manganese	..	..	..	456
Mercury	..	..	..	848
Nickel	..	..	..	545
Platinum	..	..	..	1330
Silver	..	..	..	656
Tin	..	..	..	459
Tungsten	..	..	..	1180

(f) Timber :

Anjan (Terminatia Tomentosa)	53-60
Anjan (Hardwickia Binata)	82
Babul (Acacia arabica)	54
Bambu	71
Cocanut	57-70
Cedar (white)	22
Deal (yellow)	27
Fir	25-30
Hirda	32
Jambul	47
Kalamb (styphegyne paroifolia)	42
Khair (acacia catechu)	66
Mango	42
Oak (white)	46
Pine (red)	30
Sissue (Tali)	50
Tamarind	79
Teak	41-45
Walnut	38

(g) Solids (miscellaneous) :

Bricks	100
Bakelite	80-120
Carbon	129
Cork	15
Ebony	76
Glass (common)	160
Paper	60
Phosphorus	114
Porcelain	150

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	lbs./c ft.
Resin	67
Rubber	58
Silicon	155
Sulphur	128
Wax	60

(h) Stored Material :

Animal food	64
Alum	106
Beans (canned)	43
Boiled oil	59
Books (on shelves)	40
" Bulk	60
Butter	59
Camphor	62
Candles	32
Celluloid	84-100
" goods	10
Chains	160
Chocolate	34
Cigarettes (cases)	15
Cloth	30
Cloves bales	20
Cocoanut oil	58
Coffee bags	28-32
" beans	40
Cotton raw compressed	25-36
" pressed	17
" piece goods	25-30
" seed bags	43
Cutlery cases	37
Drugs cases	26
Dyes	28
Eggs (crates)	22
Fancy goods mixed	12
Files (cases)	56
Flour sacks	40
Fruit (dry)	60

LOADS, BENDING MOMENTS AND SHEARING FORCES

	lbs / c. ft.
Glycerine (drums)	50
Grain barley	39
oats	26
rye	45
maize	47
rice bags	50
wheat	49
Ground nuts (bags)	39
Honey	90
Hosiery (cased)	14
Ice	57
Jaggery	56
Jute bales	30
Linen goods	35
Machinery cases	28
Manila ropes	32
Milk	64
" cases	38
" powder	23
Oilcake bags	41
Paint aluminium	70
bituminous	70
red lead	195
zinc	150
Perfumery (cases)	28
Rags (baled)	13
Rubber cases	25
" raw	50
Salt bulk	60
" bags	45
Soap (boxed)	57
Soft drinks cases	27
Starch	59
Sugar bags	45-50
Tea chests	22
Tobacco packets	18
Wine bulk	61
Wine bottles in cases	37

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(ii) Structural items, ceiling, finishes, etc.

Asbestos cement flat sheets $\frac{1}{4}$ " thick $2\frac{1}{2}$ lbs./s.ft.

	lbs./c.ft.
Concrete reinforced	144 to 150
with 1% steel ..	148
2% ..	151
5% ..	161
Concrete: plain ..	140
" with brick aggregate	120
" breeze ..	70 to 90
" lime ..	120
" pumice ..	50 to 55
" sawdust ..	70
" aerated or cell ..	16
Flooring: cork 1" thick	2
fibre board ..	1 $\frac{1}{2}$
granolithic ..	12
hardwood $\frac{3}{4}$ " in mastic	4
macadam tar 1" thick	11
terrazzo ..	12

	lbs./c.ft.
Masonry : ashlar ..	165
rubble ..	150
dry rubble ..	130
brick ..	120

	lbs./s.ft.
Partitions: 9" brickwork ..	90
3" breeze ..	24
2" hollow block ..	9
3" ..	12 $\frac{1}{2}$
4" ..	15
G. I. sheets ..	3
lath & plaster ..	8
clay tile partitions	
3" thick	18

LOADS, BENDING MOMENTS AND SHEARING FORCES

	lbs./s ft.
Plasters: lime 1" thick	9
cement "	11
gypsum "	7
Roofing : asbestos sheet	
½" thick ..	3½
asbestos sheet	
roofing complete	10
bituminous felt ..	1½
boarding soft wood	
¾" thick ..	2
G.I. sheets 24 G ..	1
" " 18 G ..	2
G.I. sheet roofing	
complete with	
purlins etc. ..	4
Ruberoid 5 layers.	1½
Shingles ..	1½
Slates 1-5" thick	7
Tiling clay ..	8½
" Mangalore	
" with battens	14
" single country	
" with battens	14
" double country	
" with battens	24
Thatching 9" inclu-	
ding frame	10
" 6" inclu-	
ding frame	6½

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3.2 LIVE LOADS.

(a) London Building Bye-Laws.

No	Description	Loading in Lbs., s.ft. of floor area	
		Slabs	Beams
1.	Residential Rooms, Corridors, Stairs Landings within curtilage of Residence	50 or $\frac{560}{S}$ whichever is more	40 or $\frac{2240}{S}$
2.	Office floors above entrance floor	80 or $\frac{840}{S}$	50 or $\frac{4480}{S}$
3.	Office floor, entrance floor & below entrance floor	80 or $\frac{840}{S}$	80 or $\frac{4480}{S}$
	Retail Shops, Garages for Cars 2½ Ton wt. Maximum	Add 20 lbs. s.ft. for partitions in case of offices.	
4.	Corridors, stairs & landings except those in Class I	100 or $\frac{840}{S}$	100 or $\frac{4480}{S}$
5.	(a) Workshop & Factories	150 or $\frac{840}{S}$	120 or $\frac{4480}{S}$
	(b) Garages for Cars over 2½ Tons.	150 or 1.5 Max. Combined wheel load	120 or 1.5 Max. wheel load combined.
6.	Ware Houses, Book stores, Stationery Stores	200 or $\frac{840}{S}$	200 or $\frac{4480}{S}$

ADDITIONAL FLOORS SPECIFIED BY D.S.L.R. CODE OF PRACTICE

1.	Hotel Bed Rooms, Hospital Rooms & Wards	As (1)	Above
2.	Churches, Schools, Reading Rooms, Art Galleries	As (3)	Above
3.	Assembly Halls, Drill Halls, Dance Halls, Gymnasiums, Public Spaces in Hotels & Hospitals, Theatres, Cinemas, Restaurants Grand Stalls.	As (4)	Above
1.	Roofs Inclination < 20° to Horizontal Do " " > " " " " (Loads to be taken on Plan Area)	50 15 lbs. s.ft. Normal to surface acting inwards on windward side. 10 lbs. s.ft. normal to surface and acting outwards on leeward side	30

Note. In Case of Nos. 5 & 6 above use actual loading if more than specified above.
S denotes span in feet.

LOADS, BENDING MOMENTS AND SHEARING FORCES

(b) B.S. Code..

No.	Description.	Normal	Min. Total Load lbs.	
		Load lbs./s.ft.	Slabs	Beams
1.	Dwelling > 2 Storeys	30	240	1920
	Do < 2 .. Flats.			
	Hotel Bed Rooms, Hospital	40	320	2560
	Rooms & Wards.			
	Public Rooms in Hotels	100	800	6400
2.	Office Rooms	50	400	3200
	Bank Halls Public Offices ..	70	560	4480
	Filing & Record Rooms ..	100	800	6400
	Light Storage Space ..	150		
	General storage space, Ware Houses	200		
	Retail Shops	80		
3.	Light Workshops (Min.) ..	60		
	Do. including Machinery	100	800	6400
	Circulation space in machinery halls	80	640	5120
	Medium workshop, Light Storage			
	Space	150		
	Heavy Workshops, General Storage			
	Space	200		
4.	Churches, Chapels, Restaurants			
	(with fixed seating)	80	640	5120
	School & College Class Rooms ..	60	480	3840
	Dance Halls (without fixed seating)	100	800	6400
5.	Roof : Flat < 10° to Horizontal ..	30	240	
	" Inclined (> 10° > 65° to Horizontal) ..	10		

Notes : Stairs Landing & Corridors : Design for same load as floor to which access is given but with max. load=80 lbs./s.ft. (min. load on slabs to be 640 lbs. and for beams=5120 lbs.). Same loads apply to places of assembly with fixed seating.

(c) Typical American Building Code—Live Loads.

	Lbs./s.ft.
1. Residences	40
2. Places for Assembly or Public Purposes	100
3. Class Rooms of Schools or other places of Instruction ..	75
4. Offices	50
5. Floors or any other Class not included above	120
6. Roofs Pitch < 20°	40
7. " > 20°	30
8. Side Walks between Curb & Building	300
9. Yards & Courts inside the Building Line	120

(d) Old L.C.C. Regulation (1909) — Live Loads.

	Lbs./sq. ft.
1. Domestic Buildings	70
2. Asylum Wards, Lodging House Bed Rooms, Hospital	
Wards, Hotel Bed Rooms, Work House Wards etc.	84
3. Counting Houses, Offices etc.	100
4. Art Galleries, Chapels, Churches, Class Rooms, Lecture	
Halls, Music Halls, Public Halls, Workshops, Retail	
Shops, Theatres etc. etc.	112
5. Ball Rooms, Drill Room, Floors subjected to Vibration	150
6. Book Stores, Museums, Ware Houses etc.	224

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3.3 FORMULAE for B. M. and S.F.

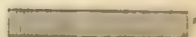
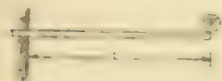
3.3-1 CANTILEVERS

LOAD DIAGRAM

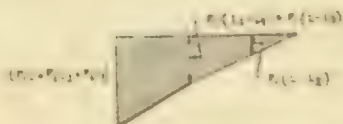
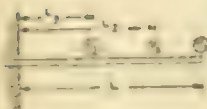
B.M. DIAGRAM

S.F. DIAGRAM

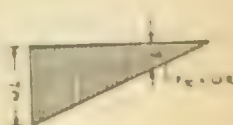
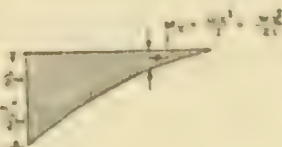
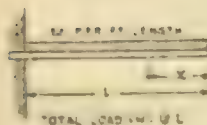
3.3-1



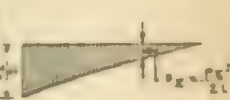
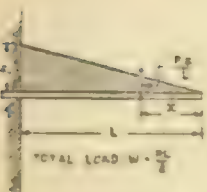
3.3-2



3.3-3



3.3-4

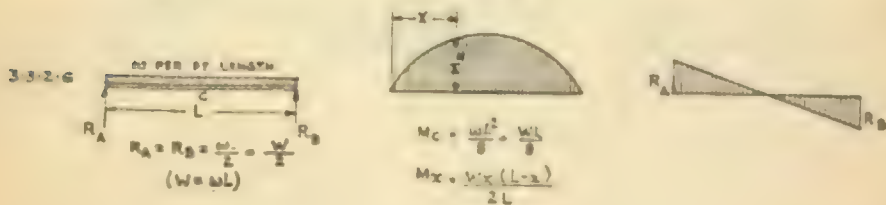
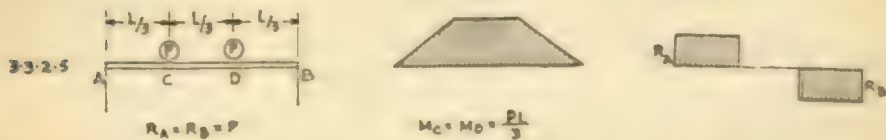
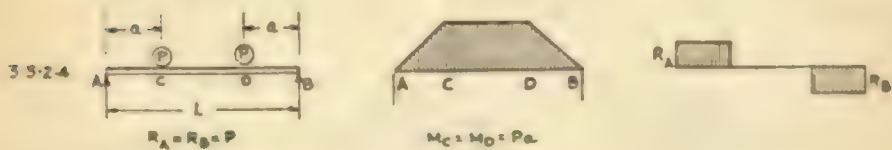
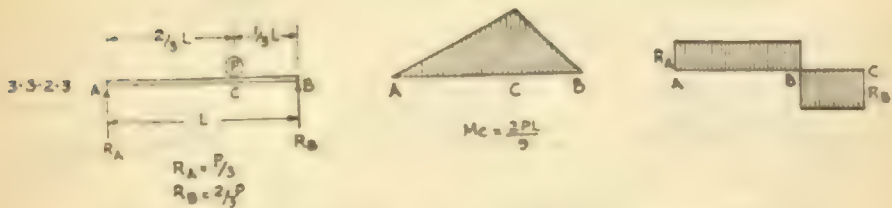
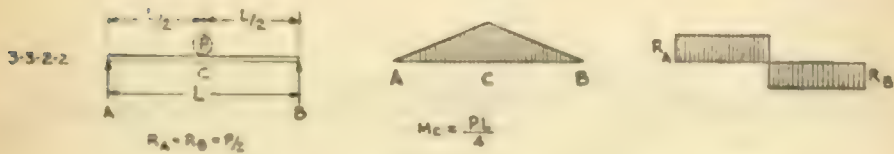
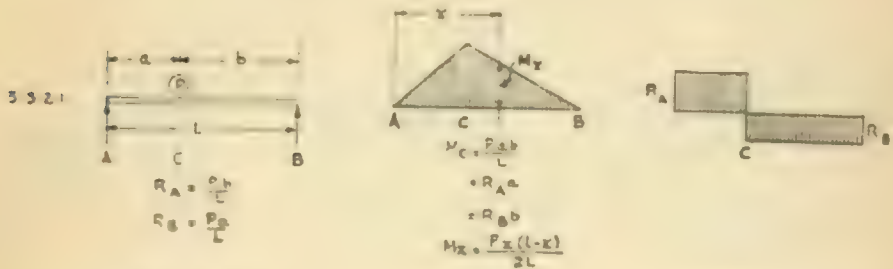


3.3-5



LOADS, BENDING MOMENTS AND SHEARING FORCES

3-3-2 SIMPLY SUPPORTED BEAMS



CONCRETE ENGINEERS' HANDBOOK

SIMPLY SUPPORTED BEAMS

3-3-2-7



$$R_A = \frac{w}{L} \left(\frac{L}{2} + c \right)$$

$$R_B = \frac{w}{L} \left(\frac{L}{2} + a \right)$$



$$M_{MAX} = \frac{w}{b} \left(\frac{L^2}{2} - a^2 \right)$$

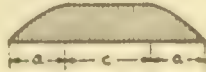
$$\text{WHERE } y = a - \frac{R_A}{w} b$$



3-3-2-8



$$R_A = w/z = R_B$$



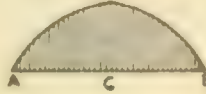
$$M_C = \frac{w a^2}{4}$$



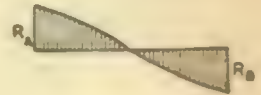
3-3-2-9



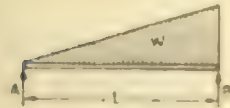
$$R_A = R_B = \frac{wL}{2}$$



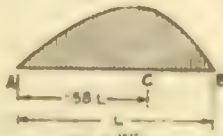
$$M_C = \frac{wL^3}{6}$$



3-3-2-10

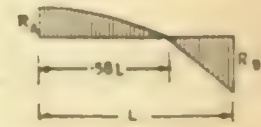


$$R_A = \frac{w}{3} \quad R_B = \frac{2w}{3}$$

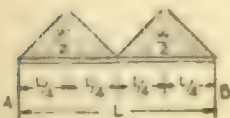


$$M_C = \frac{wL^2}{8}$$

$$M_x = \frac{wx}{8} \left(\frac{L^2}{4} - x^2 \right)$$



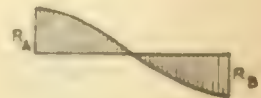
3-3-2-11



$$R_A = \frac{w}{2} = R_B$$



$$M_C = \frac{wL^3}{8}$$



LOADS, BENDING MOMENTS AND SHEARING FORCES

3-3-3 PROPPED CANTILEVER



$$R_A = \frac{11P}{16}$$

$$R_B = \frac{5P}{16}$$



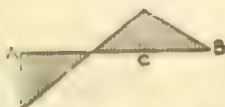
$$M_A = -\frac{3PL}{16}$$

$$M_C = +\frac{PL}{6.4}$$



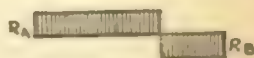
$$R_A = \frac{Pb(3L^2 - b^2)}{2L^3}$$

$$R_B = \frac{Pa^2(2L + b)}{2L^3}$$



$$M_A = -\frac{Pab(L+b)}{2L^3}$$

$$M_C = +\frac{Pa^2b(2L+3b)}{2L^3}$$



$$R_A = \frac{(2L^2 + 3La - 3a^2)P}{2L^3}$$

$$R_B = \frac{(2L^2 - 3La + 3a^2)P}{2L^3}$$



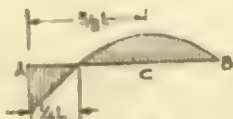
$$M_A = -\frac{3Pa(L-a)}{2L}$$

$$M_C = +\frac{Pa(2L^2 - 3La + 3a^2)}{2L^2}$$



$$R_A = \frac{5}{8}wL$$

$$R_B = \frac{3}{8}wL$$



$$M_A = -\frac{wL^2}{8}$$

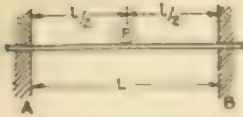
$$M_C = +\frac{wL^2}{14.2}$$



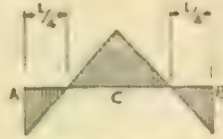
CONCRETE ENGINEERS' HANDBOOK

3-3-4 FIXED ENDED BEAMS

3-3-4-1



$$R_A = R_B = P/2$$

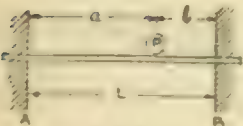


$$M_A = M_B = \frac{P}{8}$$

$$M_C = \frac{P}{8}$$



3-3-4-2



$$R_A = \frac{P a^2}{L^3} (L + 2b)$$

$$R_B = \frac{P b^2}{L^3} (L + 2a)$$



$$M_A = \frac{P a^2 b^2}{L^3}$$

$$M_B = \frac{P a^2 b^2}{L^3}$$

$$M_C = \frac{2 P a^2 b^2}{L^3}$$

$$M_{MAX} = M_B$$



3-3-4-3



$$R_A = \frac{7P}{27}$$

$$R_B = \frac{20P}{27}$$



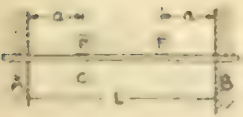
$$M_A = \frac{PL}{18.1}$$

$$M_B = \frac{PL}{18.1}$$

$$M_C = \frac{PL}{18.1}$$



3-3-4-4

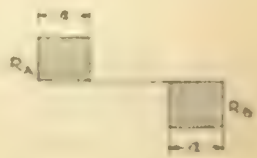


$$R_A = R_B = P$$



$$M_A = M_B = P a (L-a)$$

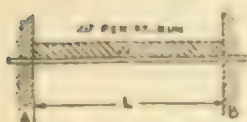
$$M_C = \frac{P a^2}{L}$$



LOADS, BENDING MOMENTS AND SHEARING FORCES

FIXED ENDED BEAMS

3-3-4-5



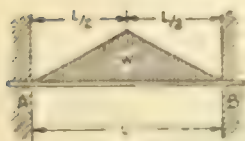
$$R_A = \frac{wL}{2} = \frac{W}{2}, R_B = \frac{W}{2}$$



$$M_A = M_B = -\frac{wL^2}{24} = -\frac{WL^2}{24}$$



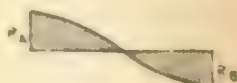
3-3-4-6



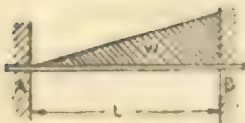
$$R_A = R_B = \frac{W}{2}$$



$$M_A = M_B = -\frac{WL}{96}$$

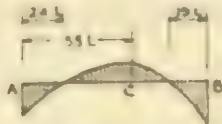


3-3-4-7



$$R_A = \frac{3W}{10}$$

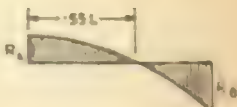
$$R_B = \frac{7W}{10}$$



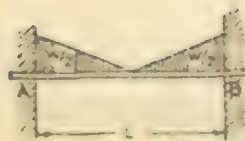
$$M_A = -\frac{WL}{10}$$

$$M_B = \frac{WL}{10} \text{ (Max)}$$

$$M_C = \frac{WL}{25}$$



3-3-4-8



$$R_A = R_B = \frac{W}{2}$$



$$M_A = M_B = -\frac{WL}{24}$$

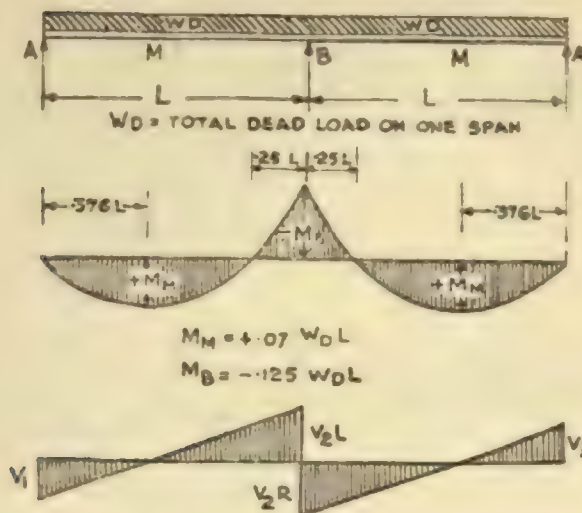
$$M_C = \frac{WL}{24}$$



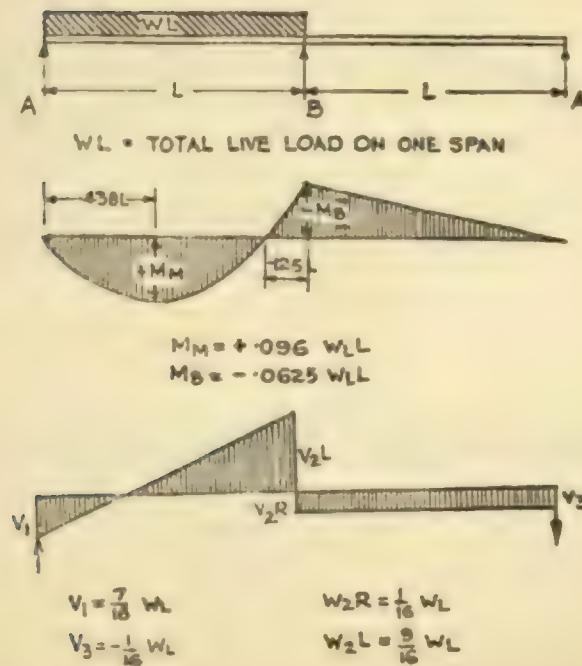
CONCRETE ENGINEERS' HANDBOOK

3-3-5 TWO EQUAL SPANS

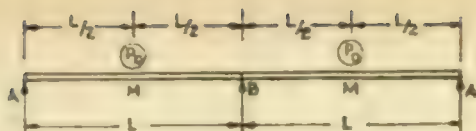
3-3-5-1



3-3-5-2



335.3



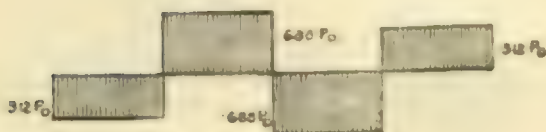
P_D = CONCENTRATED DEAD LOAD
ON CENTRE OF EACH SPAN



DEAD LOAD MOMENTS

$$M_M = + 156 P_D L$$

$$M_B = - 108 P_D L$$

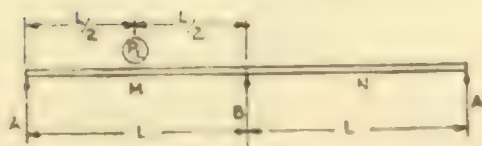


DEAD LOAD SHEARS

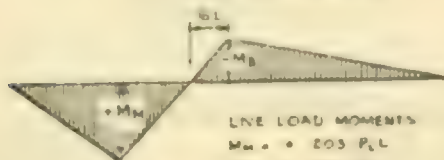
$$V_1 = - 312 P_D = V_3$$

$$V_2 L = V_2 R = 600 P_D$$

335.4



P_L = CONCENTRATED LIVE LOAD
ON CENTRE OF ONE SPAN

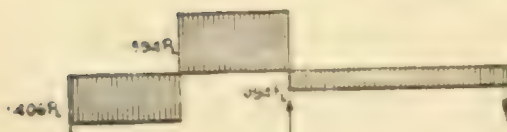


LIVE LOAD MOMENTS

$$M_M = + 203 P_L L$$

$$M_B = - 094 P_L L$$

$$M_N = + 041 P_L L$$



LIVE LOAD SHEARS

$$V_1 = - 406 P_L$$

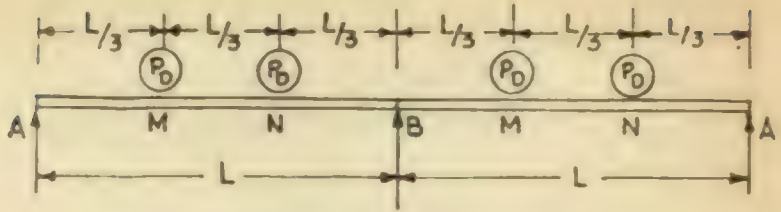
$$V_2 L = 594 P_L$$

$$V_3 = - 094 P_L$$

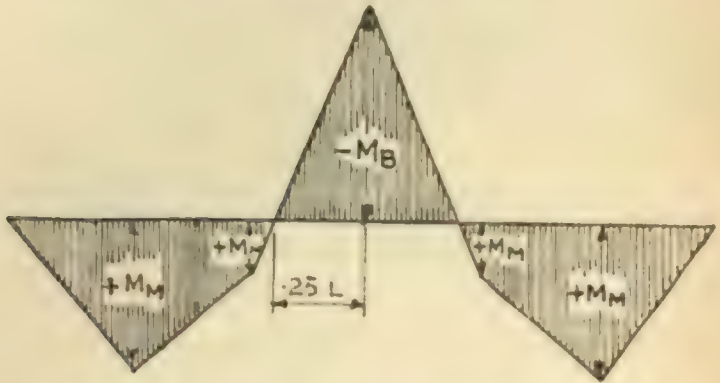
$$V_2 R = 094 P_L$$

CONCRETE ENGINEERS' HANDBOOK

3-3-5-5



P_D = CONCENTRATED DEAD LOAD
AT 3RD POINT OF EACH SPAN

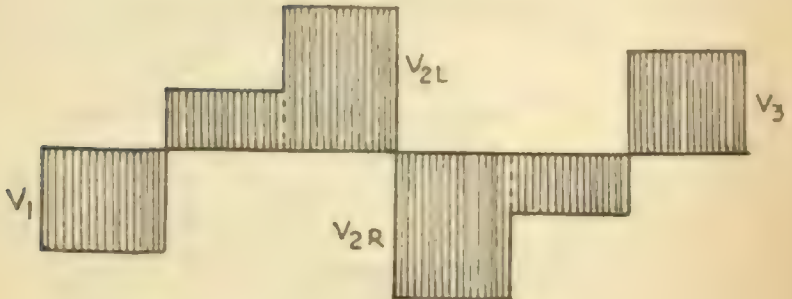


DEAD LOAD MOMENTS

$$M_M = 0.222 P_D L$$

$$M_N = 0.111 P_D L$$

$$M_B = -0.333 P_D L$$



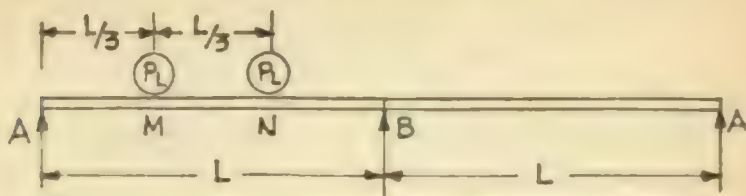
DEAD LOAD SHEARS

$$V_1 = V_3 = 0.667 P_D$$

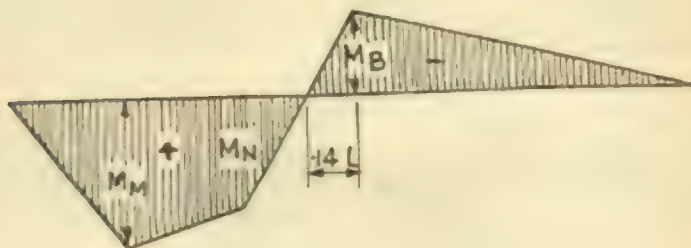
$$V_{2L} = V_{2R} = 1.333 P_D$$

LOADS, BENDING MOMENTS AND SHEARING FORCES

3.3.5.6



CONCENTRATED LIVE LOADS AT
3RD POINTS OF ONE SPAN ONLY



LIVE LOAD MOMENTS

$$M_M = .277 P_L L$$

$$M_N = .222 P_L L$$

$$M_B = -.167 P_L L$$



LIVE LOAD SHEARS

$$V_1 = .833 P_L$$

$$V_2 = 1.167 P_L$$

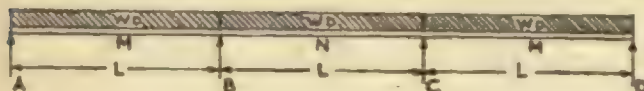
$$V_3 = -.167 P_L$$

CONCRETE ENGINEERS' HANDBOOK

3-3-6 THREE SPAN BEAMS BOTH ENDS FREE, EQUAL SPANS

ALL SPANS UNIFORMLY LOADED

3-3-6-1



W_D = TOTAL DEAD LOAD
ON ONE SPAN

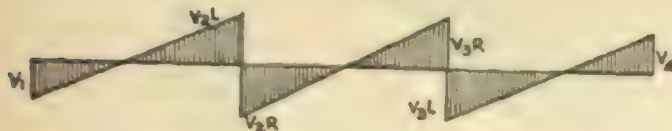


DEAD LOAD MOMENTS

$$M_A = +0.08 W_D L$$

$$M_B = +0.05 W_D L$$

$$M_C = -0.1 W_D L$$



DEAD LOAD SHEARS

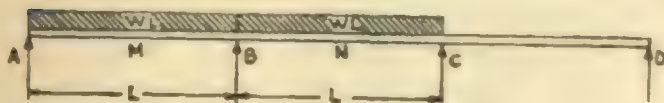
$$V_1 = V_4 = 0.4 W_D$$

$$V_{2L} = V_{3L} = 0.5 W_D$$

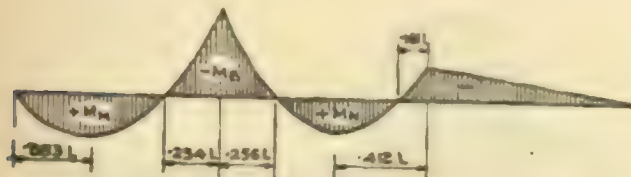
$$V_{2R} = V_{3R} = 0.6 W_D$$

TWO ADJACENT SPANS LOADED

3-3-6-2



W_L = TOTAL LIVE LOAD
ON ONE SPAN



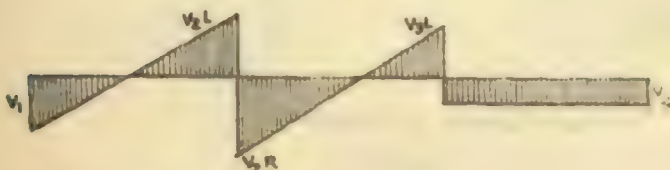
LIVE LOAD MOMENTS

$$M_A = +0.0733 W_L L$$

$$M_B = +0.0533 W_L L$$

$$M_C = -0.117 W_L L$$

$$M_D = -0.033 W_L L$$



LIVE LOAD SHEARS

$$V_1 = 0.383 W_L$$

$$V_{2R} = 0.617 W_L$$

$$V_{2L} = 0.583 W_L$$

$$V_{3L} = 0.417 W_L$$

$$V_4 = 0.083 W_L$$

LOADS, BENDING MOMENTS AND SHEARING FORCES

CENTRAL SPAN LOADED UNIFORMLY

3363



LIVE LOAD MOMENTS

$$M_B = +0.075 W_L L$$

$$M_B = M_C = -0.05 W_L L$$



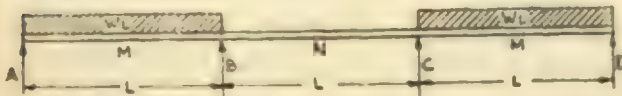
LIVE LOAD SHEARS

$$V_1 = V_4 = 0.05 W_L$$

$$V_2 R = V_3 L = 0.5 W_L$$

END SPANS LOADED UNIFORMLY

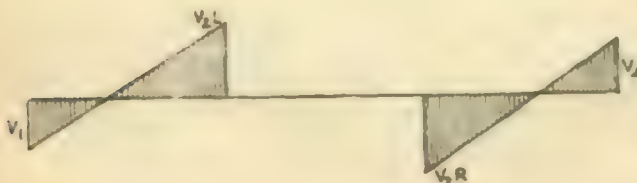
3364



LIVE LOAD MOMENTS

$$M_B = +0.101 W_L L$$

$$M_B = M_C = -0.05 W_L L$$

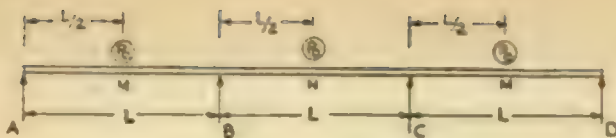


LIVE LOAD SHEARS

$$V_1 = 0.45 W_L$$

$$V_{2L} = V_{2R} = 0.55 W_L$$

3365



DEAD LOAD MOMENTS

$$M_M = +0.173 P_0 L$$

$$M_B = -0.15 P_0 L$$

$$M_N = +0.10 P_0 L$$

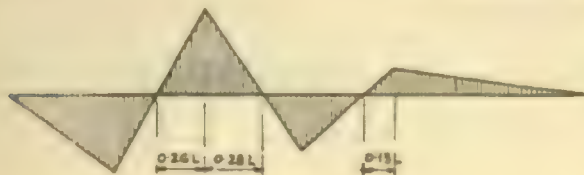
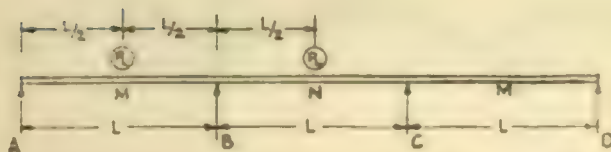


$$V_A = -0.35 P_0 = V_D$$

$$V_{B_L} = -0.65 P_0$$

$$V_{B_R} = -0.50 P_0$$

3366



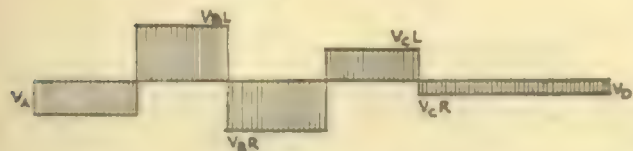
LIVE LOAD MOMENTS

$$M_M = +0.162 P_L L$$

$$M_N = +0.138 P_L L$$

$$M_B = -0.175 P_L L$$

$$M_C = -0.05 P_L L$$



$$V_A = -0.225 P_L$$

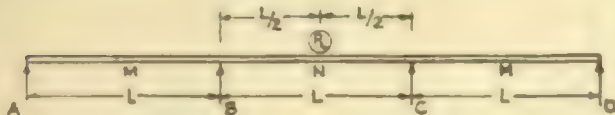
$$V_{B_L} = -0.675 P_L$$

$$V_{B_R} = -0.625 P_L$$

$$V_{C_L} = -0.375 P_L$$

$$V_{C_R} = 0.05 P_L = V_D$$

3367



$$M_B = -0.075 P_L L$$

$$M_N = +0.175 P_L L$$



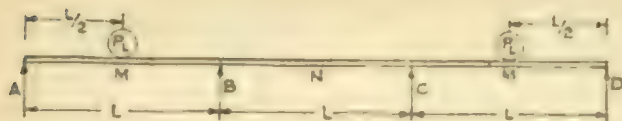
$$V_A = -0.075 P_L = V_D$$

$$V_{B_L} = -0.075 P_L = V_{C_R}$$

$$V_{B_R} = 0.5 P_L = V_{C_L}$$

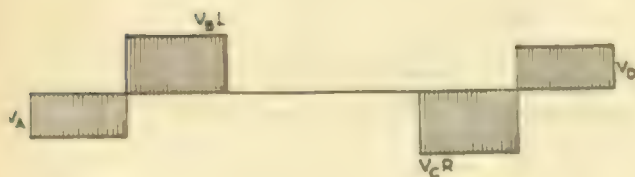
LOADS, BENDING MOMENTS AND SHEARING FORCES

3.3.6.8



$$M_M = +0.212 P_L L$$

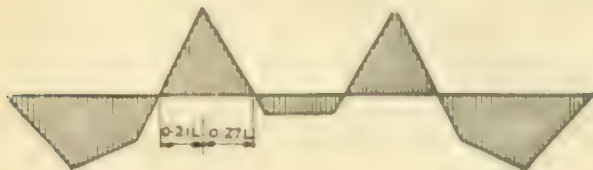
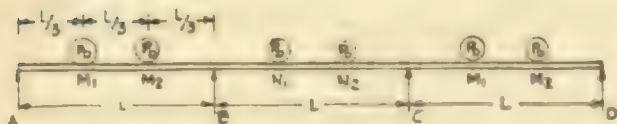
$$M_B = -0.075 P_L L$$



$$V_A = +0.425 P_L = V_D$$

$$V_{BL} = -0.575 P_L = V_{CR}$$

3.3.6.9

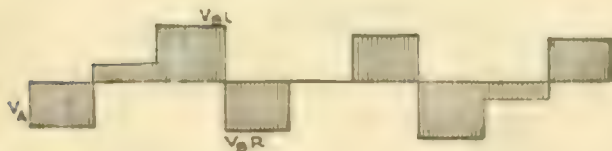


$$M_{M_1} = +0.245 P_0 L$$

$$M_{M_2} = +0.126 P_0 L$$

$$M_B = -0.267 P_0 L$$

$$M_{N_1} = +0.0667 P_0 L$$

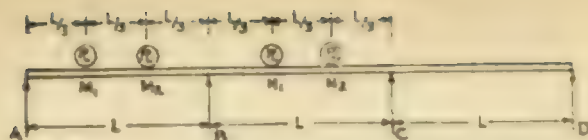


$$V_A = 0.73 P_0$$

$$V_{BL} = 1.27 P_0$$

$$V_{CR} = 1.00 P_0$$

3.3.6.10

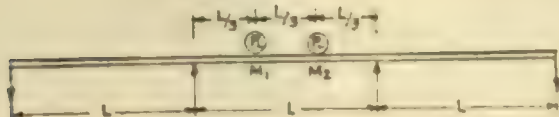


$$\begin{aligned} M_{M_1} &= +0.229 P_1 L \\ M_{M_2} &= +0.126 P_1 L \\ M_B &= -0.311 P_1 L \\ M_{M_1} &= +0.056 P_1 L \\ M_{M_2} &= +0.170 P_1 L \\ M_C &= -0.089 P_1 L \end{aligned}$$



$$\begin{aligned} V_A &= 0.689 P_L \\ V_{BL} &= 1.311 P_L \\ V_{BR} &= 1.222 P_L \\ V_{CL} &= 0.778 P_L \\ V_{CR} &= 0.089 P_L \end{aligned}$$

3.3.6.11

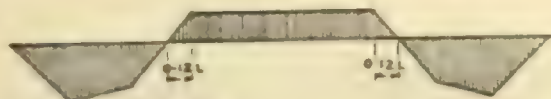


$$\begin{aligned} M_B &= -0.133 P_L L \\ M_{M_1} &= +0.2 P_L L \end{aligned}$$

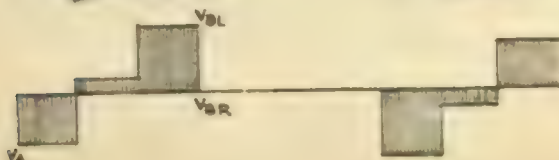


$$\begin{aligned} V_A &= 0.133 P_L \\ V_{BL} &= 0.133 P_L \\ V_{BR} &= 1.0 P_L \end{aligned}$$

3.3.6.12



$$\begin{aligned} M_{M_1} &= +0.289 P_L L \\ M_{M_2} &= +0.245 P_L L \\ M_B &= -0.133 P_L L \end{aligned}$$



$$\begin{aligned} V_A &= 0.867 P_L \\ V_{BL} &= 1.133 P_L \\ V_{BR} &= 0.00 P_L \end{aligned}$$

LOADS, BENDING MOMENTS AND SHEARING FORCES

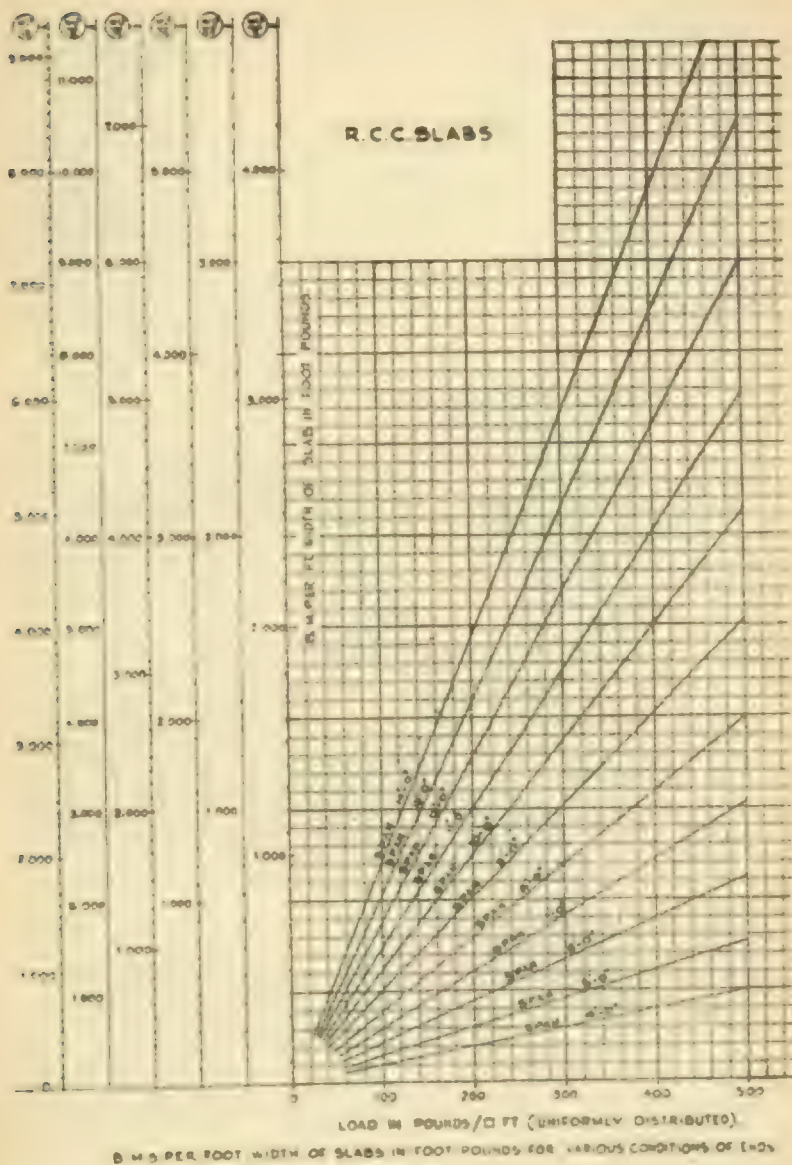


Fig. 3-1

CONCRETE ENGINEERS' HANDBOOK

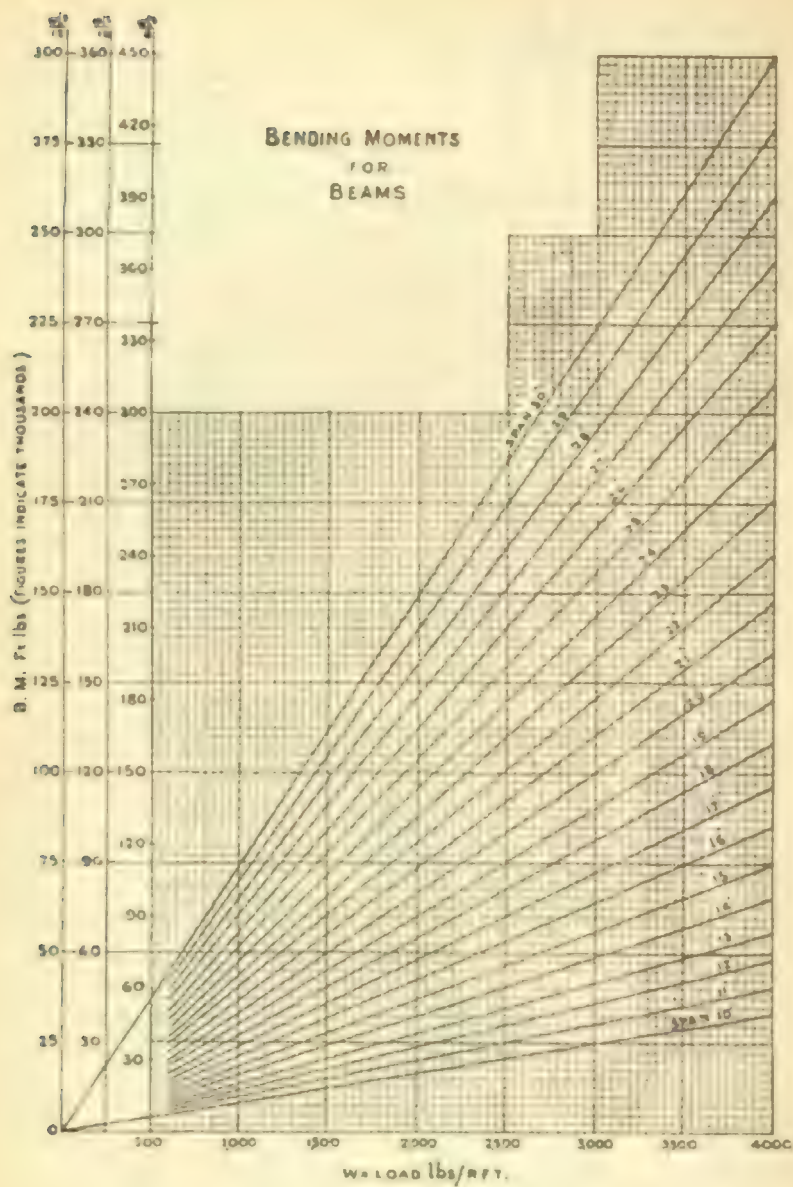


Fig. 3-2

3.4 B. Ms. FOR R.C.C. SLABS
(Ready Calculated)

TABLE 5a

L	W																								
		40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480	500
4	wl ² /8	40	120	160	200	240	280	320	360	400	440	480	520	560	600	640	680	720	760	800	840	880	920	960	1000
	wl ² /10	64	9	128	160	192	224	256	288	320	352	384	416	448	480	512	544	576	608	640	672	704	736	768	800
	wl ² /12	53.33	80	106.7	133.3	160	186.7	213.3	240	266.7	293.3	320	346.7	373.3	400	426.7	453.3	480	506.7	533.3	560	586.7	613.3	640	666.7
5	wl ² /8	125	167.5	250.0	310.5	375	437.5	500	562.5	625	687.5	750	812.5	875	937.5	1000	1062.5	1125	1187.5	1250	1312.5	1375	1437.5	1500	1562.5
	wl ² /10	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250
	wl ² /12	83.33	125	166.7	208.3	250	291.7	333.3	375	416.7	458.3	500	541.7	583.3	625	666.7	708.3	750	791.7	833.3	875	916.7	958.3	1000	1041.7
6	wl ² /8	180	270	360	450	540	630	720	810	900	990	1080	1170	1260	1350	1440	1530	1620	1710	1800	1890	1980	2070	2160	2250
	wl ² /10	144	216	288	360	432	504	576	648	720	792	864	936	1008	1080	1152	1224	1296	1368	1440	1512	1584	1656	1728	1800
	wl ² /12	120	180	240	300	360	420	480	540	600	660	720	780	840	900	960	1020	1080	1140	1200	1260	1320	1380	1440	1500
7	wl ² /8	245	367.5	490	612.5	735	857.5	980	1102.5	1225	1347.5	1470	1592.5	1715	1837.5	1960	2082.5	2205	2327.5	2450	2572.5	2695	2817.5	2940	3062.5
	wl ² /10	196	294	392	490	588	686	784	882	980	1078	1176	1274	1372	1470	1568	1666	1764	1862	1960	2058	2156	2254	2352	2450
	wl ² /12	163.3	245	326.6	408.3	490	571.6	653.3	735	816.6	898.3	979.9	1061.6	1143.2	1224.9	1306.6	1388.2	1469.9	1551.6	1633.2	1714.9	1796.6	1878.2	1959.9	2041.6
8	wl ² /8	320	480	640	800	960	1120	1280	1440	1600	1760	1920	2080	2240	2400	2560	2720	2880	3040	3200	3360	3520	3680	3840	4000
	wl ² /10	256	384	512	640	768	896	1024	1152	1280	1408	1536	1664	1792	1920	2048	2176	2304	2432	2560	2688	2816	2944	3072	3200
	wl ² /12	213.33	320	426.6	533.3	640	746.6	853.3	960	1066.6	1173.3	1280	1386.6	1493.3	1600	1706.6	1813.3	1920	2026.6	2133.3	2240	2346.6	2453.3	2560	2666.6
9	wl ² /8	405	607.5	810	1012.5	1215	1417.5	1620	1822.5	2025	2227.5	2430	2632.5	2835	3037.5	3240	3442.5	3645	3847.5	4050	4252.5	4455	4657.5	4860	5062.5
	wl ² /10	324	486	648	810	972	1134	1296	1458	1620	1782	1944	2106	2268	2430	2592	2754	2916	3078	3240	3402	3564	3726	3888	4050
	wl ² /12	270	405	540	675	810	945	1080	1215	1350	1485	1620	1755	1890	2025	2160	2295	2430	2565	2700	2835	2970	3105	3240	3375
10	wl ² /8	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000	3250	3500	3750	4000	4250	4500	4750	5000	5250	5500	5750	6000	6250
	wl ² /10	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400	4600	4800	5000
	wl ² /12	333.3	500	666.6	833.3	1000	1166.6	1333.3	1500	1666.6	1833.3	2000	2166.6	2333.3	2500	2666.6	2833.3	3000	3166.6	3333.3	3500	3666.6	3833.3	4000	4166.6
11	wl ² /8	605	907.5	1210	1512.5	1815	2117.5	2420	2722.5	3025	3327.5	3630	3932.5	4235	4537.5	4840	5142.5	5445	5747.5	6050	6352.5	6655	6957.5	7260	7562.5
	wl ² /10	484	726	968	1210	1452	1694	1936	2178	2420	2662	2904	3146	3388	3630	3872	4114	4356	4598	4840	5082	5324	5566	5808	6050
	wl ² /12	403.3	605	806.6	1008.3	1210	1411.6	1613.3	1815	2016.6	2218.3	2420	2621.6	2823.3	3025	3226.6	3428.3	3630	3831.6	4033.3	4234.9	4436.6	4638.3	4840	5041.6
12	wl ² /8	720	1080	1440	1800	2160	2520	2880	3240	3600	3960	4320	4680	5040	5400	5760	6120	6480	6840	7200	7560	7920	8280	8640	9000
	wl ² /10	576	864	1152	1440	1728	2016	2304	2592	2880	3168	3456	3744	4032	4320	4608	4896	5184	5472	5760	6048	6336	6624	6912	7200
	wl ² /12	480	720	960	1200	1440	1680	1920	2160	2400	2640	2880	3120	3360	3600	3840	4080	4320	4560	4800	5040	5280	5520	5760	6000
13	wl ² /8	845	1267.5	1690	2112.5	2535	2957.5	3380	3802.5	4225	4647.5	5070	5492.5	5915	6337.5	6760	7182.5	7605	8027.5	8450	8872.5	9295	9717.5	10140	10562.5
	wl ² /10	676	1014	1352	1690	2028	2366	2704	3042	3380	3718	4056	4394	4732	5070	5408	5746	6084	6422	6760	7098	7436	7774	8112	8450
	wl ² /12	563.3	845	1126.7	1408.3	1690	1971.6	2253.3	2535	2816.6	3098.3	3379.9	3661.6	3943.2	4224.9	4506.6	4788.2	5069.9	5351.6	5633.2	5914.9	6196.6	6478.2	6759.9	7041.6
14	wl ² /8	976	1464	1952	2440	2928	3416	3904	4392	4880	5368	5856	6344	6832	7320	7808	8296	8784	9272	9760	10248	10736	11224	11712	12200
	wl ² /10	784	1176	1568	1960	2352	2744	3136	3528	3920	4312	4704	5096	5488	5880	6272	6664	7056	7448	7840	8232	8624	9016	9408	9800
	wl ² /12	653.3	980	1306.6	1633.3	1960	2286.6	2613.3	2940	3266.6	3593.3	3920	4246.6	4573.3	4900	5226.6	5553.3	5880	6206.6	6533.3	6860	7186.6	7513.3	7840	8166.6

BENDING MOMENTS IN POLY8 FEET FOR SLABS

L=SPAN IN FEET

W=LOAD PER SQ. FOOT



3.5 B. M. FOR BEAMS
(Ready Calculated).

TABLE 16
Values of bending moments for beams in ft/pounds

$$M = \frac{WL}{12}$$

L W	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1000	8333	10083	12000	14883	18333	18750	21833	24083	27000	30083	33333	36750	40333	44083	48000	52083	56333	60750	65333	70083	75000
1100	8408	11166	13200	15491	17999	20625	23466	26481	29700	33091	36667	40425	44366	48491	52800	57291	61966	66825	71866	77091	82500
1200	10000	12188	14400	16900	19500	22200	25000	27900	32400	36100	40000	44100	48400	52900	57600	62500	67600	72900	78400	84100	
1300	10633	13108	15600	18288	21233	24375	27733	31308	35100	39108	43333	47775	52433	57308	62400	67708	73233	78975	84933	91108	
1400	11666	14116	16800	19716	22866	26250	29866	33716	37800	42116	46667	51450	56466	61716	67200	72916	78866	85050	91466	98108	
1500	12500	15125	18000	21125	24466	28125	32000	36125	40500	45125	50000	55125	60466	66125	72000	78091	84500	91125	97900	104925	
1600	13333	16133	19200	22533	26133	30000	34133	38533	43200	48133	53333	58800	64533	70533	76800	83333	90133	97200	104533	112108	
1700	14166	17141	20400	23941	27766	31875	36266	40941	45900	51141	56667	62466	68533	74966	81766	88933	96466	104366	112633	121266	
1800	15000	18133	21600	25366	29400	33750	38400	43340	48600	54166	60000	66150	72600	79366	86466	93933	101766	110000	118633	127666	
1900	15833	19166	22800	26766	31033	35625	40533	45756	51300	57166	63333	69825	76666	83766	91200	99000	107233	115933	125066	134633	
2000	16666	20166	24000	28166	32533	37200	42266	47666	53400	59500	66000	72866	80000	87466	95266	103500	112200	121400	131100	141333	
2100	17500	21249	25200	29574	34266	39275	44600	50241	56200	62500	69266	76400	83933	91766	100000	108733	117966	127700	138033	148966	
2200	18333	22133	26400	30983	35600	40533	45866	51500	57466	63766	70500	77666	85200	93133	101466	110200	119433	129166	139500	150433	
2300	19166	23191	27600	32361	37233	42375	47800	53533	59566	65900	72633	79766	87300	95233	103566	112300	121533	131266	141600	152533	
2400	20000	24133	28800	33749	38733	44000	49566	55400	61500	67966	74766	81900	89433	97366	105700	114433	123666	133400	143733	154666	
2500	20833	25066	30000	35066	40300	45800	51566	57600	63966	70666	77700	85133	92966	101200	109833	118866	128300	138233	148666	159600	
2600	21666	25916	31200	36416	41800	47500	53533	59900	66600	73666	81000	88733	96866	105400	114333	123666	133500	143833	154666	166000	
2700	22500	27224	32400	37824	43400	49300	55533	62100	69000	76266	83900	91933	100366	109200	118433	128066	138200	148833	159966	171600	
2800	23333	28233	33600	39233	45000	51066	57466	64200	71300	78766	86600	94833	103466	112500	121933	131766	142000	152733	163966	175700	
2900	24166	29241	34800	40641	46733	53066	59700	66600	73866	81500	89533	97966	106800	116033	125666	135700	146133	157066	168500	180433	
3000	25000	30229	36000	42250	48600	55266	62200	69500	77266	85500	94233	103466	113100	123133	133566	144400	155633	167266	179300	191833	
3100	25833	31233	37200	43633	50300	57266	64500	72100	80166	88700	97733	107266	117300	127833	138766	150100	161833	173966	186500	199533	
3200	26667	32267	38400	45067	52000	59266	66800	74700	83066	91900	101333	111366	121900	132933	144466	156500	169033	182066	195600	209633	
3300	27500	33275	39600	46475	53700	61266	69100	77466	86300	95733	105766	116400	127633	139366	151600	164433	177766	191600	206033	221066	
3400	28333	34233	40800	47833	55333	63200	71566	80500	89966	99900	110433	121566	133300	145633	158566	172000	186033	200666	215900	231733	
3500	29167	35292	42000	49292	57167	65500	74466	84000	94100	104800	116133	128166	140900	154333	168466	183300	198833	215066	231900	249433	
3600	30000	36333	43200	50700	58800	67500	77000	87200	98100	109733	122166	135400	149433	164266	179800	196133	213266	231200	250033	269766	
3700	30833	37308	44400	52108	60433	69375	79033	89500	100900	113233	126566	140800	155933	171966	188900	206733	225466	245100	265633	287066	
3800	31667	38317	45600	53517	62066	71250	81067	91600	103000	115333	128666	142900	158033	174066	191000	208833	227566	247200	267833	289466	
3900	32500	39225	46800	54925	63700	73125	83200	93925	105300	117633	130966	145200	160333	176466	193500	211433	230266	250000	270733	292466	
4000	33333	40333	48000	56333	65833	75500	86333	97366	109000	121333	134666	149000	164333	180666	198000	216333	235666	256000	277333	299666	

W = LOAD IN POUNDS PER FT.

L = SPAN IN FEET.

CHAPTER 4

DESIGN OF R.C.C. SLABS

CONTENTS

4.1 (a) Formulæ and (b) Design Constants and Stresses for calculation of r.c.c. slabs and rectangular beams.

4.2 Summary of above.

Charts and Tables.

Chart No. 4-1 Values of 'n' for different stress ratios.

Chart No. 4-2 —do.— 'p' —do.—

Table No. 4-a Design constants for different values of f_c , f_t and m .

Chart No. 4-3 Values of 'n' for different percentage of steel.

Chart No. 4-4 —do.— 'Q' —do.—

Chart No. 4-5 Details of r.c.c. slabs with different reinforcement Old L.C.C.R.

Chart No. 4-6 —do.— New L.C.C.R.

Chart No. 4-7 —do.— I.S.I. or D.S.I.R. Code

Table No. 4-b R.M. & A_t for r.c.c. slabs of various depths & mixes.

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4-h —do.—

Charts 4-9 —do.— Old L.C.C.R.

4-10 —do.— New "

4-11 —do.— I.S.I. or D.S.I.R. Code

4-12 —do.— B.S. Code

4.3 Examples illustrating use of charts and tables.

CHAPTER 4

DESIGN OF R.C.C. SLABS

4.1 (a) FORMULA FOR DESIGN OF R.C.C. SLABS AND RECTANGULAR BEAMS.

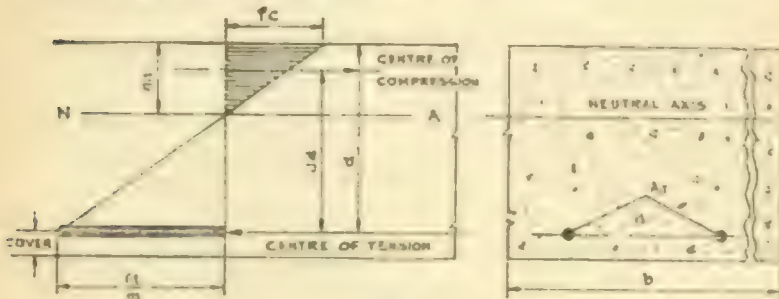


Fig. A

NOTATION.

f_c —compressive unit stress in extreme fibre of concrete.

The following values are adopted in practice for 1 : 2 : 4 concrete

$f_c = 600$ lbs/ \square "	Old L.C.C. Regulations	
$f_c = 750$..	New L.C.C. By Laws (Ordinary Grade)	

950 ..	-do-	(Quality A Grade)
--------	------	-------------------

$f_c = 750$..	D.S.I.R. or I.S.I. Code of Practice (Ordinary Grade)	
----------------	--	--

950 ..	-do-	(High Grade)
--------	------	--------------

1188 ..	-do-	(Special Grade)
---------	------	-----------------

1000 ..	B. S. Code	(Aggregates as per B.S. 882)
---------	------------	------------------------------

$f_t = 16000$ lbs/ \square "	Old L.C.C. Regulations	
$= 18000$..	New -do-	D.S.I.R. & B.S. Codes

= 20000 ..	High Yield Point Mild Steel	
= 25000 ..	Hard Drawn Steel Wire	

m —modular ratio i.e. $\frac{\text{Modulus of elasticity of steel}}{\text{Modulus of elasticity of concrete}}$

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The following values of m are assumed in practice:

$m=15$ (New & Old L.C.C.R.) and B.S. Code of Practice

$$m = \frac{40,000}{3 f_c} \left\{ \begin{array}{l} \text{D.S.I.R. Code of Practice} \\ \text{I.S.I.} \end{array} \right\}$$

i.e. $m=17.78$ for ordinary grade
 $=14.03$ " High Grade
 $=11$ " Special Grade.

R.M.—Moment of resistance or bending moment in pounds inches

At—Cross-sectional area of re-inforcement in tension in sq. inches.

b—breadth of beam or slab in inches

d—effective depth of beam or slab in inches

n—ratio of depth of neutral axis to depth **d**

j—ratio of lever arm, of resisting couple to depth **d**

jd—lever arm

$$p = \frac{A_t}{bd} = \text{ratio of area of tension steel to effective area of concrete}$$

4.1 (b) DESIGN CONSTANTS & STRESSES.

(i) Stresses

	f_c	f_t	m	Ref
Old L.C.C.R.	600	16000	15	(a)
New L.C.C.R.				
Ordinary grade	750	18000	15	(b)
Quality A grade	950	18000	15	(c)
D.S.I.R. or ISI. Code of Practice				
Also Railway code of Practice				
Ordinary grade	750	18000	18	(d)
High grade	950	18000	14	(e)
Special grade	1188	18900	11	(f)
B.S. Code of Practice				
Aggregates according to B.S. 882	1000	18000	15	(g)
Aggregates not according to B.S. 882	750	18,000	15	(h)

(ii) Constants

$$n = \frac{m f_c}{m f_c + f_t} \text{ or } \frac{1}{1 + \frac{f_t}{m f_c}} \quad (1)$$

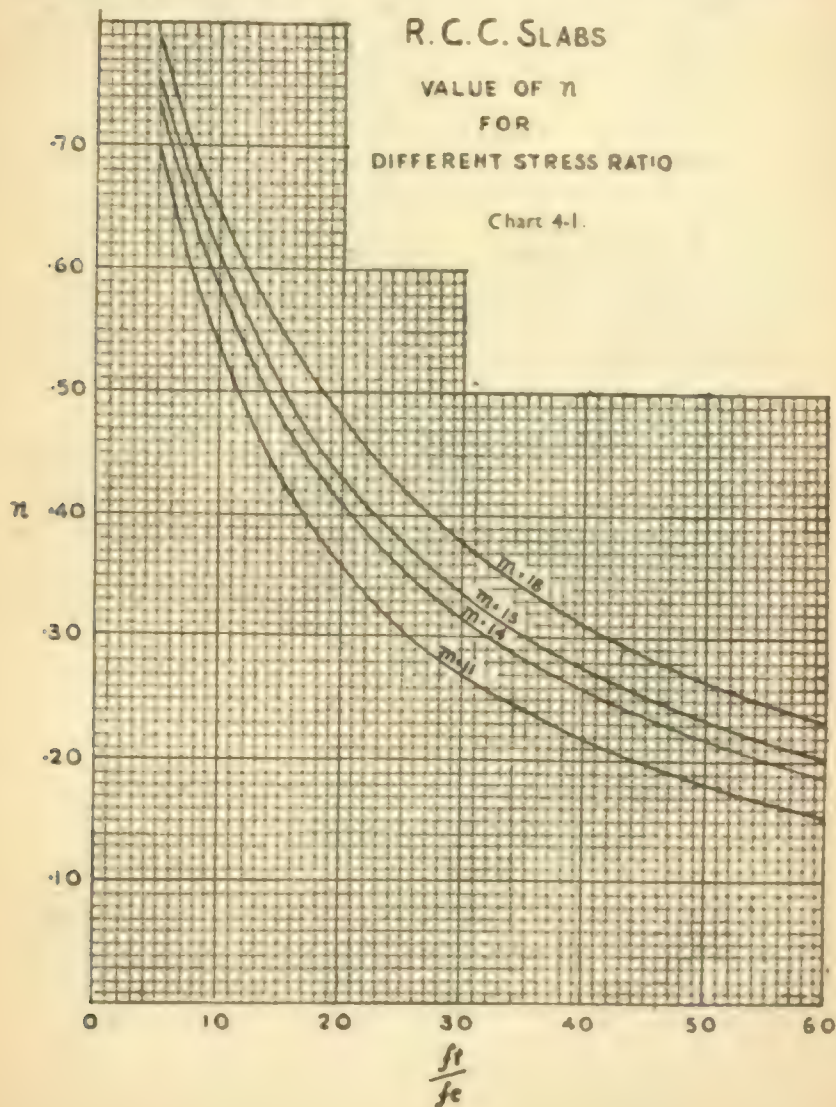
$n = .36$	for case a
$= .385$	" " b & h
$= .44$	" " c
$= .430$	" " d

DESIGN OF R.C.C. SLABS

— .430	for case e
— .423	" " f
— .455	" " g

The location of neutral axis is always governed by the stress ratio $\frac{f_t}{f_c}$ and modular ratio m .

The values of n for different values of f_t/f_c and m are given in graph No. 4-1.



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$$j = 1 - \frac{n}{3} \dots\dots\dots (2)$$

$j = .88$	for case a
$= .87$	" " b & h
$= .853$	" " c
$= .86$	" " d
$= .86$	" " e
$= .858$	" " f
$= .848$	" " g

$$A_t = \frac{f_c}{f_t} \times \frac{nbd}{2} = pbd \dots\dots\dots (3)$$

or

$$p = \frac{f_c}{f_t} \times \frac{n}{2}$$

$A_t = .00675 \text{ } bd$ or .675% of the effective sectional area of the section for case a

$= .008 \text{ } bd$ or .8 %	for case b & h
$= .0117 \text{ } bd$ or 1.17%	" " c
$= .0089 \text{ } bd$ or .89%	" " d
$= .0112 \text{ } bd$ or 1.12%	" " e
$= .0140 \text{ } bd$ or 1.40%	" " f
$= .0126 \text{ } bd$ or 1.26%	" " g

(b & d measured in inches)

The percentage of reinforcement depends upon the location of neutral axis and stress ratio. The value of p is given in graph No. 4-2 for different values of $\frac{f_t}{f_c}$ and m

DESIGN OF R.C.C. SLABS

R.C.C. SLABS

VALUES OF p
FOR
DIFFERENT STRESS RATIO

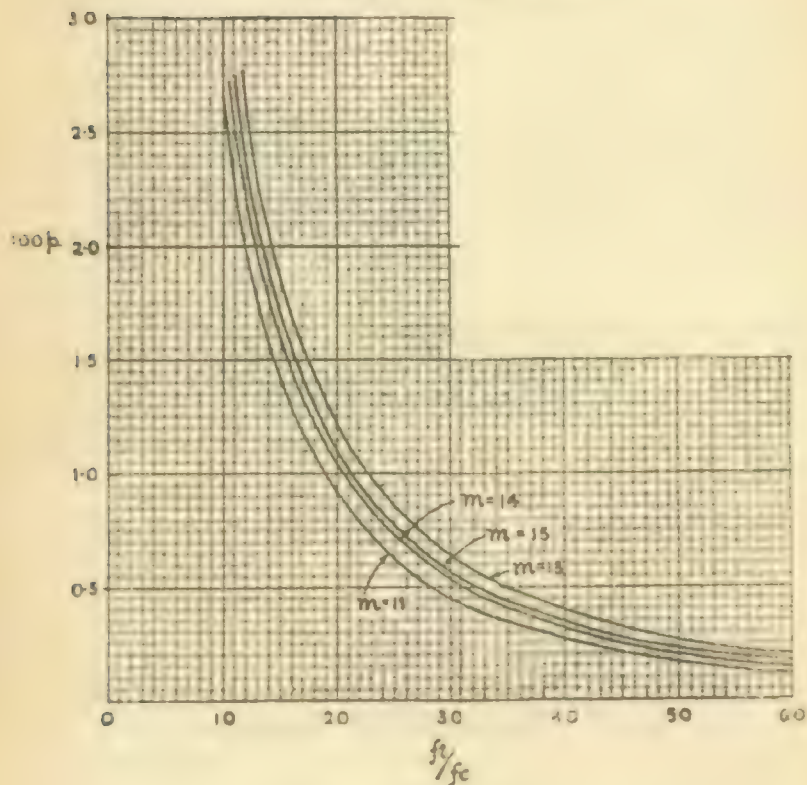


Chart 4-2.

$$\text{R.M.} = \begin{cases} f_t A_t j d \\ \text{or} \\ f_c n_j b d^2 \end{cases} = Q b d^2 \quad \begin{matrix} (b \text{ \& } d \text{ measured} \\ \text{in inches}) \end{matrix}$$

$Q = 95$	for case a
126	" " b & h
179	" " c
137	" " d
173.3	" " e
217	" " f
192.8	" " g

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Design constants for various values of f_c , f_t & m are given in table No. 4-a.

Values of R.M. & A_t for slabs of various depths designed for stresses specified by the different codes are given in table 4-b and chart No. 4-3.

The amount of steel as given by formula (3) is the economic amount i.e. both the steel and concrete are stressed to the maximum permitted limits. If steel more than that calculated by formula (3) is used, the steel will be understressed and safe R.M. of the slab will be governed by the concrete. If less steel is used, the concrete will be understressed and the safe R.M. will be governed by steel. The following procedure is necessary to find the safe R.M. of the slab in such cases.

- a. To find the neutral axis of the slab by the formula

$$n = \sqrt{p^2 m^2 + 2 pm} - pm$$

The values of n for $m=11$ to 18 & $p=.002$ to $.02$ are plotted in graph No. 4-3.

- b. Find lever arm $j = d - \frac{n}{3}$

- c. Find R.M. R.M. = $A_t f_t j d$ when steel provided is less than economic

$$\text{or R.M.} = \frac{f_c}{2} n j b d^2 \text{ when steel provided is more than economic}$$

$$\text{In general R.M.} = Q b d^2$$

The different values of Q are given in graph No. 4-4 for different values of p & $m=15$ and $m=18$. R.M.s. for different depths of slab designed as per different codes and reinforced with different amount of steel are given in charts 4-5, 4-6 and 4-7.

DESIGN OF R.C.C. SLABS

R. C. C. SLAB

VALUES OF η FOR VARIOUS PERCENTAGES OF STEEL

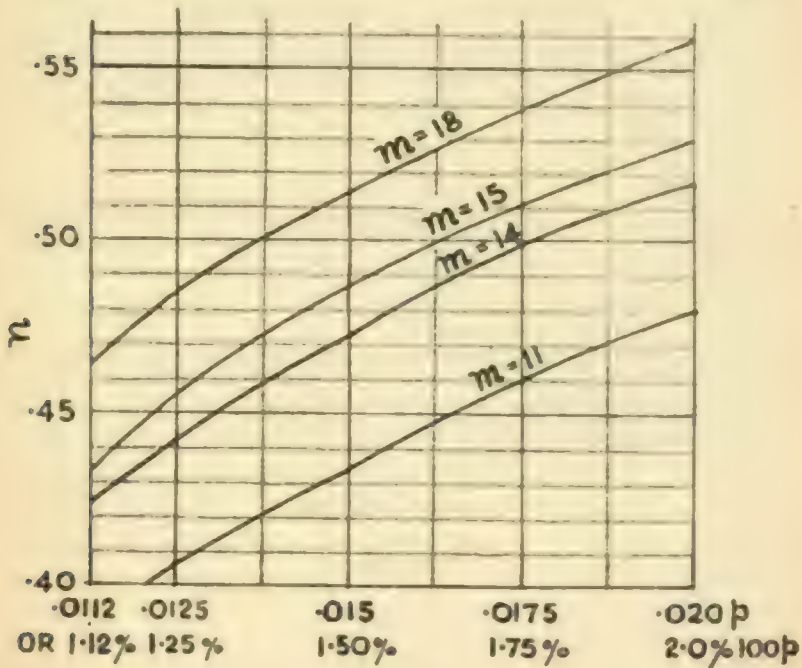
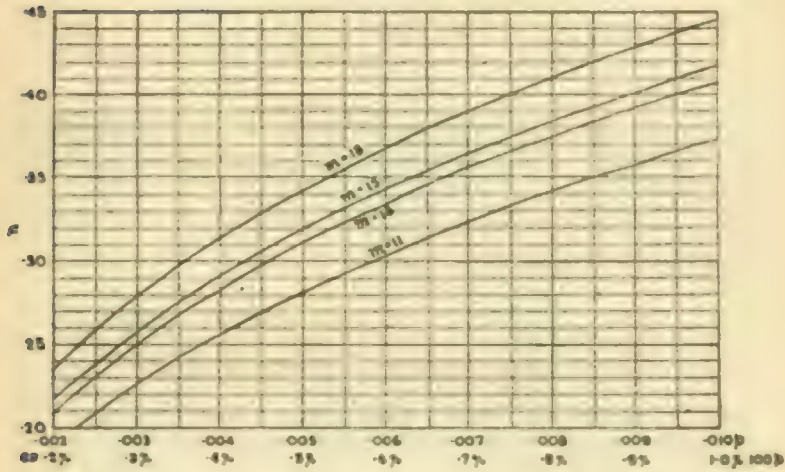


Chart 4-3

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R.C.C. SLAB

Q FOR VARIOUS PERCENTAGES OF STEEL

FOR

a: $f_c = 750$ $f_t = 18000$ $m = 18$

b: 750 18000 $m = 15$

c: 600 16000 $m = 15$

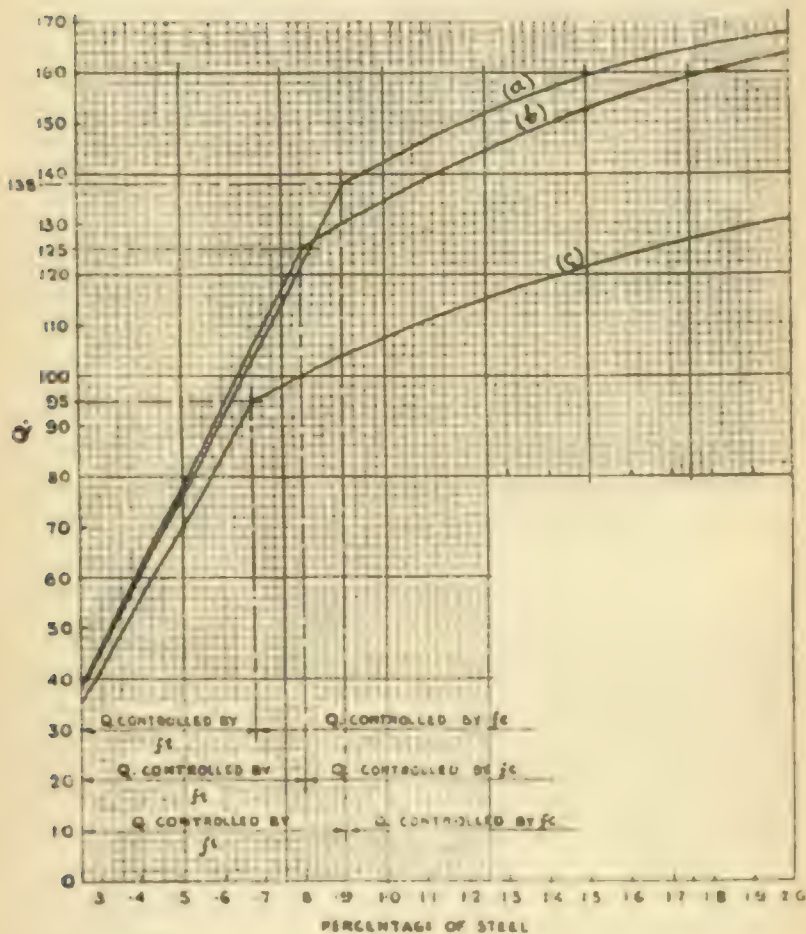


Chart 4 4

DESIGN OF R.C.C. SLABS

R. C. C. SLABS

R. M. FOR VARIOUS AMOUNTS OF STEEL

$$m = 15$$

$$f_c = 500 \text{ lbs/sq in}$$

$$f_s = 10000 \text{ lbs/sq in}$$

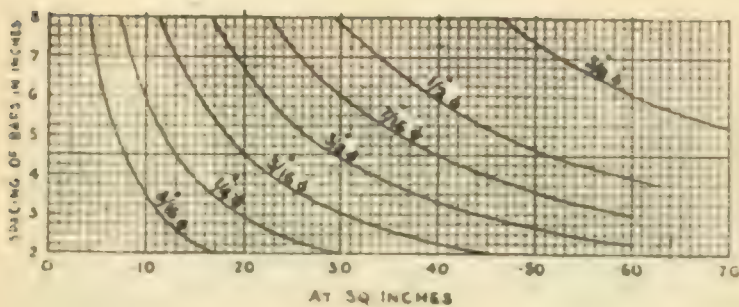
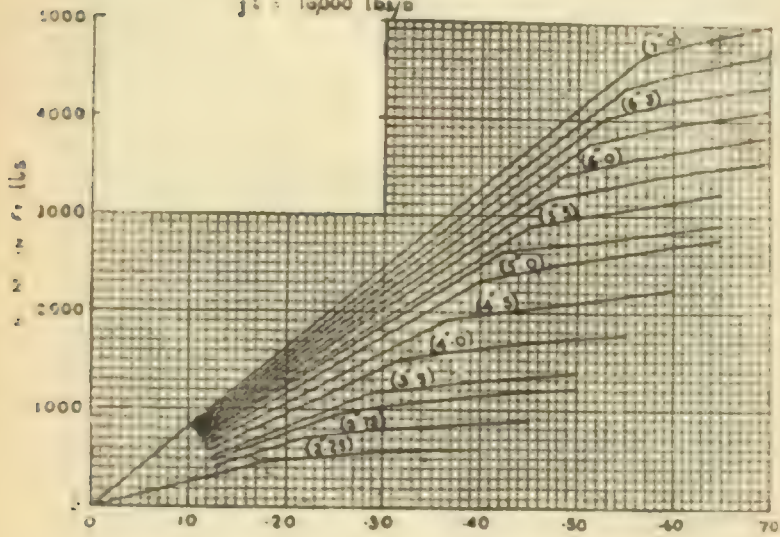


Chart 4-5

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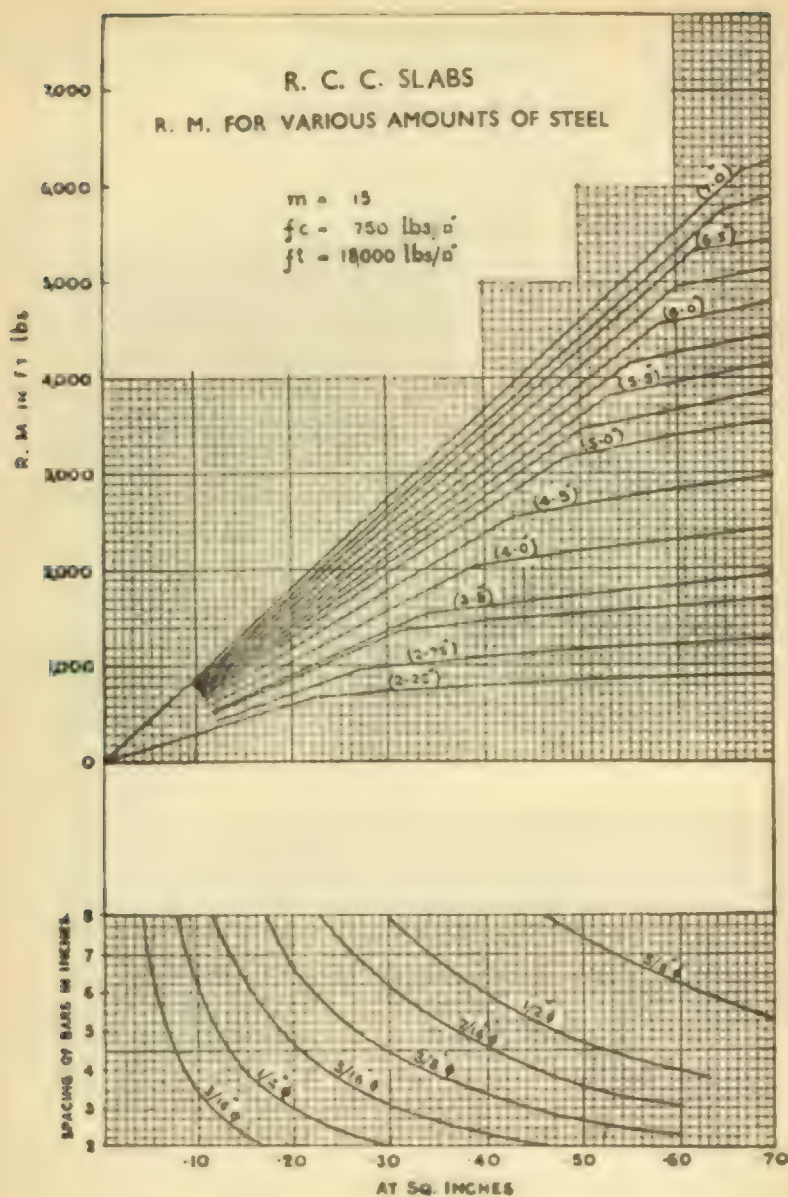


Chart 4-6

DESIGN OF R.C.C. SLABS

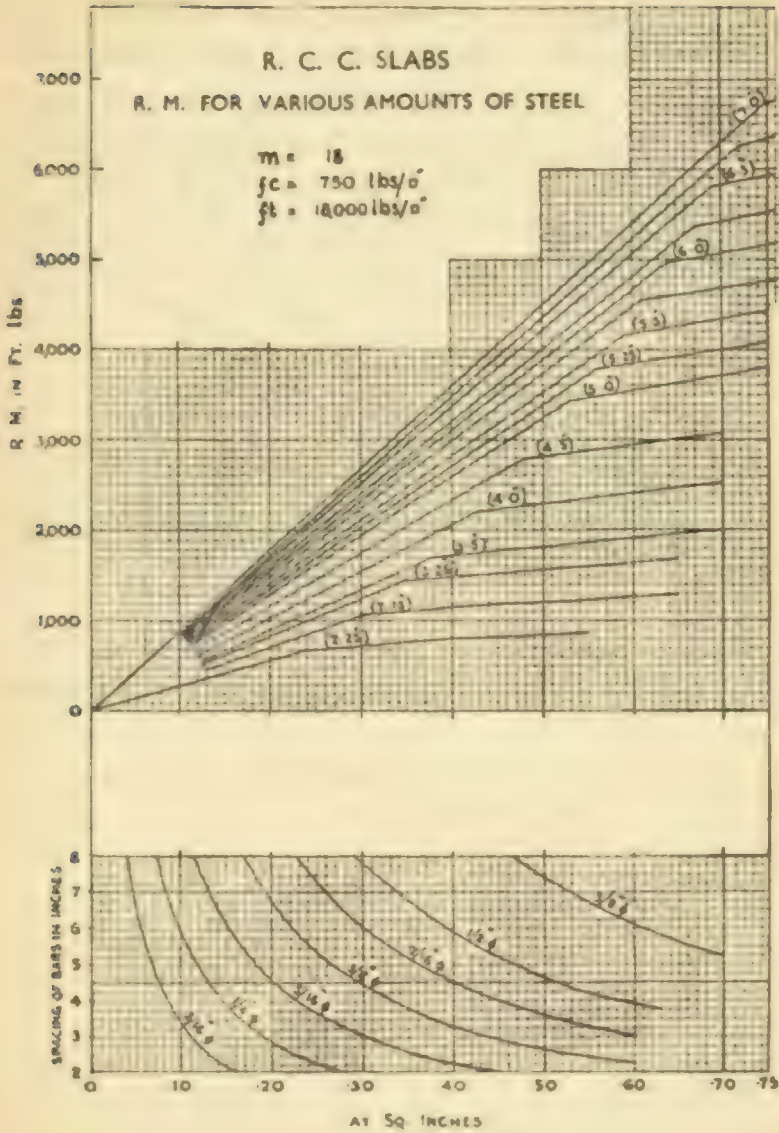


Chart 4-7

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4.2 SUMMARY.

NAME	fc lbs \square	ft lbs \square	m	n	pd	At %	Q
Old L.C.C.R. ..	600	16000	15	.36	.88	.675	95
New L.C.C. Ordinary ..	750	18000	15	.385	.87	.8	126
Do A Grade ..	950	18000	15	.44	.853	1.17	179
D.S.I.R. Code Ordinary (Also Indian Railway Code)	750	18000	18	.43	.86	.89	137
Do. High Grade	950	18000	14	.43	.86	1.12	173.3
Do. Special Grade	1188	18000	11	.423	.858	1.40	217
B.S. Code of Practice Aggts as per B.S. 882 ..	1000	18000	15	.455	.848	1.26	192.8
Other aggts. ..	750	18000	15	.39	.87	.8	126
Proposed I.S. Code of Practice ..							
Ordinary Grade ..	750	18000	18	.43	.86	.89	137

TABLE 4a.

fo	fo	m=15				m=16				m=17				fo	m=18			
		q	p	r	s	q	p	r	s	q	p	r	s		q	p	r	s
10000	400	69-0	0001	273	900	55-5	0039	310	897	47-1	0025	160	213	600	79-1	0005	290	905
	450	69-2	0042	297	901	66-7	0048	335	888	57-1	0040	285	305	650	80-1	0007	309	907
	500	71-3	0050	319	894	70-2	0064	360	880	68-1	0048	304	899	700	81-3	0071	321	892
	550	83-0	0060	340	887	91-8	0066	383	872	79-1	0050	325	892	750	112-0	0060	340	887
	600	93-0	0065	360	880	104-7	0070	403	866	81-1	0064	344	885	800	125-2	0069	355	882
	650	107-3	0077	379	874	117-8	0086	422	859	100-0	0074	363	879	850	137-4	0088	369	877
	700	120-4	0087	396	866	131-3	0096	440	853	113-0	0083	380	872	900	150-0	0107	382	873
	750	133-5	0097	413	862	145-1	0107	456	848	129-1	0092	396	865	950	162-0	0117	395	868
	800	146-9	0107	429	857	159-1	0118	472	843	142-2	0103	412	860	1000	176-2	0128	407	864
	850	160-4	0118	443	852	174-0	0130	489	837	156-4	0114	427	854	1050	189-3	0138	419	860
15000	900	174-3	0129	458	847	189-4	0141	503	832	169-1	0124	441	849	1100	203-0	0148	431	857
	950	188-4	0140	471	843	203-5	0154	517	826	183-2	0135	454	845	1200	220-7	0173	432	849
	400	44-8	0023	250	917	51-5	0032	265	905	43-7	0026	237	921	600	73-3	0045	268	911
	450	53-8	0034	273	909	62-7	0039	311	896	55-1	0032	250	914	650	83-6	0061	284	905
	500	66-3	0041	294	902	74-1	0046	354	889	67-5	0039	280	907	700	94-4	0068	300	900
	550	77-4	0048	314	895	86-1	0054	394	882	79-1	0048	299	900	750	106-5	0066	314	895
	600	88-0	0056	333	889	98-2	0062	434	875	91-4	0053	318	894	800	118-9	0073	329	891
	650	100-8	0063	351	883	111-3	0071	474	869	104-6	0061	338	888	850	131-8	0081	342	886
	700	113-1	0072	368	877	124-4	0080	512	863	118-9	0069	363	882	900	146-9	0089	355	882
	750	125-7	0080	385	872	137-7	0089	550	857	131-1	0077	388	877	950	162-2	0097	367	878
20000	800	138-7	0089	400	867	151-6	0099	585	851	145-1	0086	404	872	1000	165-7	0105	379	874
	850	151-0	0098	415	862	165-1	0108	620	847	158-0	0094	420	867	1050	178-0	0114	391	870
	900	163-3	0107	429	857	179-0	0119	654	842	169-0	0103	432	863	1100	183-5	0123	403	866
	950	179-0	0117	442	853	194-0	0128	687	838	181-0	0112	445	858	1200	218-0	0141	423	860
	1000	193-0	0126	455	848	208-0	0139	700	833	197-0	0121	458	854					
	400	42-4	0023	231	923	48-1	0026	264	912	40-2	0022	219	917	600	68-1	0027	248	917
	450	53-0	0028	253	916	58-5	0032	288	904	49-8	0027	240	909	650	78-3	0040	263	912
	500	65-0	0034	273	909	69-5	0039	311	896	59-2	0032	250	904	700	89-6	0049	278	907
	550	72-6	0040	292	903	81-0	0046	331	890	69-2	0038	276	907	750	98-9	0055	292	903
	600	83-5	0047	310	897	92-9	0053	356	883	80-2	0044	298	900	800	109-8	0061	306	899
	650	94-9	0053	328	891	105-2	0060	380	877	91-1	0051	318	896	850	121-0	0068	319	894
	700	106-7	0060	344	885	117-7	0068	404	871	102-4	0058	339	890	900	132-4	0075	331	890
	750	118-8	0068	360	880	130-8	0076	423	866	114-2	0066	364	885	950	144-4	0082	343	886
25000	800	131-2	0075	375	875	144-0	0084	445	860	128-2	0072	389	880	1000	156-4	0090	355	882
	850	144-0	0083	389	870	157-8	0092	464	855	138-6	0079	403	875	1050	168-6	0098	366	878
	900	157-0	0091	403	866	172-0	0101	484	851	151-0	0087	427	871	1100	181-3	0106	377	874
	950	170-2	0099	418	861	186-5	0109	501	846	164-3	0095	450	867	1200	204-9	0115	388	869

VALUES OF DESIGN CONSTANTS FOR DIFFERENT VALUES OF f_0 (C. 4. a)

DESIGN OF R.C.C. SLABS

TABLE 4-b.
RM & At for R.C.C. slabs of various depths for different mixes.

MIX	"A"		"B & H"		C		D		E		F		G	
	R.M. (Ft. lbs.)	At (sq")	R.M.	At	R.M.	At	R.M.	At	R.M.	At	R.M.	At	R.M.	At
2.25	481	182	638	216	906	316	699	240	877	302	1103	381	977	340
2.75	728	223	963	264	1354	386	1644	294	1331	370	1649	465	1459	416
3.25	1003	263	1350	312	1890	456	1457	347	1830	437	2290	550	2038	491
3.50	1164	283	1543	336	2183	491	1690	374	2123	470	2671	592	2304	520
4.00	1520	324	2016	384	2864	562	2208	427	2773	538	3488	677	3068	606
4.50	1924	365	2550	432	3625	632	2795	480	3509	606	4416	761	3907	680
5.00	2375	405	3150	480	4475	702	3450	534	4333	672	5450	840	4623	756
5.25	2618	426	3473	504	4933	737	3803	560	4776	706	6008	888	5319	794
5.50	2874	446	3812	528	5415	772	4176	587	5242	730	6595	930	5838	832
5.75	3141	466	4166	552	5917	807	4563	614	5729	773	7297	973	6361	869
6.00	3340	486	4536	576	6484	842	4968	641	6379	806	7848	1.02	6946	907
6.25	3611	506	4922	600	6992	878	5390	668	6769	841	8515	1.06	7639	946
6.50	4013	527	5324	624	7563	913	5830	694	7322	874	9210	1.10	8154	983
6.75	4327	547	5740	648	8165	948	6283	721	7906	907	9932	1.14	8793	1.020
7.00	4655	564	6174	672	8771	983	6762	748	8512	940	10682	1.18	9457	1.055

Note.— For d not given in the Table above. Refer to Chart No. 4-b.

CONCRETE ENGINEERS' HANDBOOK

Table 4-c.
R.C.C. SLABS
Simply supported slabs ($f_c=600$, $f_t=16000$, $m=15$)

Total Depth of Slab (inches)	SPAN IN FEET												DETAILS OF SLAB			
	SALE LOAD (INCLUDING WEIGHT OF SLAB) W_s <input type="checkbox"/> P_c												Minimum of Reinforcement R.M. Per Sq. Yd.	REINFORCEMENT (round bars)		QUANTITIES Per 100 sq. ft.
	4'	5'	6'	7'	8'	9'	10'	11'	12'	13'	14'	15'	16'	Main	Distribu-	
															tion	Concrete cu. Yd.
3"	238	162	106	76	60	47							481	1 1/4" @ 3"	3 1/2" @ 6 1/2"	25.60
3 1/2"		239	158	110	90	70	57						718	3 3/8" @ 5 1/2"	" 10"	29.17
4"		318	221	165	124	98	80	66					1063	" 5"	1 1/4" @ 12"	33.03
4 1/2"		372	258	190	145	115	93	76					1163	" 4 1/2"	1 1/4" @ 14"	37.50
5"		444	336	248	189	149	121	100	84	72			1520	" 4"	1 1/4" @ 15"	41.67
5 1/2"			312	239	189	153	125	106	90	76			1926	" 3 1/2"	Do	45.83
6"			385	295	215	180	156	137	112	96	82		2375	1 1/2" @ 6"	Do	50.00
6 1/2"			425	325	257	209	172	144	122	106	93	81	2618	" 5 1/2"	1 1/4" @ 14"	52.08
6 3/4"			470	350	284	230	190	160	137	118	102	90	2874	" 6"	1 1/2" @ 12"	56.17
6 3/8"			606	399	307	260	205	173	147	127	110	97	3161	" 5"	Do	59.25
7"			557	427	337	274	220	190	161	139	121	107	3450	" 5"	Do	58.33
7 1/2"			602	461	364	295	244	204	174	150	122	110	3710	" 4 1/2"	Do	60.42
7 3/4"			655	500	396	321	266	223	190	164	142	125	4013	" 4 1/2" @ 10"	1 1/4" @ 10"	62.50
7 1/8"			702	536	425	344	286	239	202	175	154	135	4328	" 4"	Do	64.58
8"			760	590	460	372	307	256	220	190	165	145	4655	" 4"	Do	66.67

* Bar spacings have been kept at round figures though theoretical values may be slightly different.

DESIGN OF R.C.C. SLABS

Table 4-d.

R.C.C. SLABS

Simply supported slabs ($f_c=750$, $f_t=18,000$, $m=15$)

SAFE LOAD (INCLUDING WEIGHT OF SLAB) Lbs/ <input type="checkbox"/> Ft													DETAILS OF SLABS							
Total Slab Depth, ft	SPAN IN FEET												Effective Depth (Inches)	Area of Steel, Sq Ft	Cover (Inches)	Moment of Resistance For Lbs./Sq. Ft.	REINFORCEMENT (ground bars)		QUANTITIES For 100 Sq. Ft.	
	4'	5'	6'	7'	8'	9'	10'	11'	12'	13'	14'	15'					Main	Distribu- tion	Concrete, Cu. Ft.	Steel, Cwts.
3'	204	142	104	80	65	51	42						2.35	216	9/16	638	3.35" @ 5 1/2"	1.4" @ 9"	25.00	1.03
3 1/2'		210	155	110	84	76	63	45					2.75	264	9/16	995	" 4 1/2"	1.4" @ 10"	29.17	1.18
4'		296	217	167	123	108	87	74	63				3.35	312	9/16	1250	" 4"	1.4" @ 12"	33.33	1.35
4 1/2'		343	253	185	135	126	103	80	73	63			3.50	336	3/4	1545	" 3 1/2"	1.4" @ 14"	37.60	1.42
5'			292	196	161	136	112	86	82				4.00	394	3/4	2016	1 1/2" @ 6"	1.4" @ 15"	41.67	1.46
5 1/2'			280	250	204	164	142	120	102	90			4.50	432	3/4	2550	" 3 1/2"	1.4" @ 16"	45.83	1.53
6'			264	310	252	208	176	150	129	112	98		5.00	480	3/4	3160	" 5"	1.4" @ 12"	50.00	1.75
6 1/2'			435	345	290	230	195	166	143	127	108		5.25	504	3/4	3475	" 4 1/2"	1.4" @ 12"	52.08	1.80
6 3/4'			478	378	305	253	212	180	156	136	110		5.50	528	3/4	3812	" 4 1/2"	1.4" @ 12"	54.17	1.90
6 3/8'			520	410	334	276	232	196	170	143	120		5.75	552	3/4	4160	1 1/2" @ 4"	1.4" @ 11"	56.25	2.12
7'			448	363	300	240	201	174	145	121	101		6.00	576	3/4	4530	1 1/2" @ 4"	1.4" @ 10"	58.33	2.33
7 1/2'			490	396	325	265	226	194	164	142	114		6.25	600	3/4	4922	1 1/2" @ 4"	1.4" @ 10"	60.42	2.43
7 3/4'			525	426	350	290	245	217	189	166	146		6.50	624	1 1/16	5324	5/8" @ 6"	1.4" @ 10"	62.50	2.50
7 1/2'			570	460	390	320	270	235	203	180	150		6.75	648	1 1/16	5710	5/8" @ 5 1/2"	1.4" @ 9"	64.58	2.55
8'			610	494	407	342	282	240	210	184	154		7.00	672	1 1/16	6174	5/8" @ 5 1/2"	1.4" @ 9"	66.67	2.59

Table 4-c.
R.C.C. SLABS
Simply supported slabs ($f_c=750$, $f_t=18000$, $m=18$)

SAFE LOAD (INCLUDING WEIGHT OF SLAB) Lbs./Sq. Ft.													DETAILS OF SLABS				QUANTITIES Per 100 sq. ft.			
Total Depth of Slab (inches)	SPAN IN FEET												Effective Depth (inches)	Area of Steel, Sq. Ft.	Cover (inches)	Minimum Reinforcement R.M. (round bars)	REINFORCEMENT		Concrete C. Ft.	Steel Cwts.
	4'	5'	6'	7'	8'	9'	10'	11'	12'	13'	14'	15'					16'	Main			Distribu- tion
3"		155	114	87	69	56	46							2-25	9/16	609	3/8" @ 5 1/2"	1/4" @ 10"	25-00	1-03
3 1/2"		231	171	131	104	83	69	56	46					2-75	9/16	1044	3/8" @ 4 1/2"	Do.	29-17	1-18
4"			240	192	164	137	99	81	69	60				3-26	9/16	1457	1/2" @ 6 1/2"	1/4" @ 9"	33-33	1-42
4 1/2"				277	211	167	136	114	95	84	69	60		3-50	3/4	1690	1/2" @ 6"	1/4" @ 8"	37-50	1-54
5"					270	218	182	151	127	108	90	78	69	4-00	-427	2/4	1/2" @ 5 1/2"	1/4" @ 7"	41-67	1-72
5 1/2"						349	276	228	185	155	132	114	99	4-50	-480	3/4	1/2" @ 5"	1/4" @ 6"	45-83	1-90
6"							430	340	276	234	191	163	141	5-00	-534	3/4	1/2" @ 4 1/2"	1/4" @ 5 1/2"	50-00	2-10
6 1/2"								376	304	252	212	180	156	5-25	-580	3/4	1/2" @ 4 1/2"	1/4" @ 5"	52-08	2-21
6 3/4"									410	332	276	231	195	5-50	-637	3/4	1/2" @ 4"	1/4" @ 5"	54-17	2-30
6 7/8"										364	300	252	216	5-75	-614	3/4	5/8" @ 6"	1/4" @ 4 1/2"	56-25	2-46
7"											397	329	276	6-00	-641	3/4	5/8" @ 5 1/2"	3/8" @ 11"	58-33	2-60
7 1/8"												450	350	6-25	-668	3/4	5/8" @ 5 1/2"	3/8" @ 10"	60-42	2-76
7 1/4"													466	6-50	-694	11/16	5/8" @ 5"	3/8" @ 9 1/2"	63-50	2-92
7 1/2"														6-75	-721	11/16	5/8" @ 6"	3/8" @ 9"	64-58	2-97
8"														7-00	-748	11/16	5/8" @ 4 1/2"	3/8" @ 9"	66-67	3-22

Table 4-g.
R.C.C. SLABS (continuous)
($f_c=750$, ft.—18,000, m.—15)

Total Depth of Slab (inches)	SEMI CONTINUOUS $\left(-\frac{WL}{10}\right)$													FULLY CONTINUOUS $\left(-\frac{WL}{12}\right)$												
	SAFE LOAD (INCLUDING WEIGHT OF SLAB) Lbs./ <input type="checkbox"/> Ft.													SAFE LOAD (INCLUDING WEIGHT OF SLAB) Lbs./ <input type="checkbox"/> Ft.												
	SPAN IN FEET													SPAN IN FEET												
	4'	5'	6'	7'	8'	9'	10'	11'	12'	13'	14'	15'	16'	4'	5'	6'	7'	8'	9'	10'	11'	12'	13'	14'	15'	16'
3'	255	177	130	100	79	64	52							300	213	156	120	94	75	63						
3½'		262	194	140	117	95	79	66	53						315	232	178	141	114	94	79	67				
4'		370	271	202	166	132	109	92	79						444	325	250	199	159	130	111	94				
4½'		429	316	242	191	155	129	107	91	79					514	370	291	229	186	154	129	109	94			
5'				315	245	201	170	140	120	102						378	294	241	204	168	144	123				129
5½'				400	312	255	210	177	150	127	112	100				480	375	305	252	213	180	153	135	120		167
6'				492	397	315	260	220	187	161	140	122				601	465	378	312	264	225	192	168	147		
6½'				544	431	350	287	244	207	179	159	135				652	517	420	345	292	246	214	190	162		
6¾'				597	470	381	320	265	225	194	170	149				717	564	457	384	319	270	237	204	178		
6¾'				650	512	417	344	290	245	212	185	162				790	615	481	412	348	294	256	222	195		
7'					560	454	375	314	267	231	201	179				872	672	544	450	375	321	277	241	214		
7½'					612	495	406	344	292	250	219	192				955	735	594	487	412	351	300	252	221		
7¾'					656	532	437	369	315	271	236	207				1038	787	639	525	442	376	325	278	249		
7¾'						712	575	475	400	337	294	254	225				1121	856	690	570	480	405	352	304	270	
8'							762	617	509	427	365	312	274	242				916	741	610	513	413	375	328	291	

DESIGN OF R.C.C. SLABS

Table 4-b.
R.C.C. SLABS (continuous)
($f_c=600$, ft.—16,000, $m=15$)

Total length of slab (feet)	SEMI CONTINUOUS ($\frac{W_L}{10}$)												FULLY CONTINUOUS ($\frac{W_L}{12}$)													
	SAFE LOAD (INCLUDING WEIGHT OF SLAB) lbs/ <input type="checkbox"/> ft.												SAFE LOAD (INCLUDING WEIGHT OF SLABS) lbs/ <input type="checkbox"/> ft.													
	SPAN IN FEET												SPAN IN FEET													
	5'	6'	7'	8'	9'	10'	11'	12'	13'	14'	15'	16'	4	5'	6'	7'	8'	9'	10'	11'	12'	13'	14'	15'	16'	
3'	207	100	132	137	75	59							227	228	150	117	90	70								
3½'		207	107	145	111	87	71							237	237	174	133	103	83							
4'			207	270	202	155	122	100	82					477	331	243	186	147	120	90						
4½'				465	322	237	181	144	110	96				558	387	285	217	172	130	114						
5'				605	420	310	236	186	151	125	105			726	504	372	283	223	181	150	126	106				
5½'					390	290	220	191	157	132	112				668	506	383	339	179	159	135	117				
6'					481	269	291	236	195	164	140	120	102			577	442	349	283	234	196	168	144	123		
6½'						531	406	321	260	215	180	152	132	116	101		637	487	386	312	258	216	183	159	139	
7'							567	449	355	287	237	200	171	147	127	113		705	538	425	343	285	240	205	177	
7½'								635	486	384	311	256	210	184	159	137	121		762	583	460	372	307	259	220	180
8'									696	534	421	342	282	237	201	174	151	134		835	640	505	411	339	285	241
8½'										752	575	455	369	305	255	217	187	165	145		903	690	546	442	366	308
9'											819	625	495	401	332	276	237	205	177	156		982	730	594	481	399
9½'												877	672	531	430	355	299	251	210	182	169		1053	807	637	516
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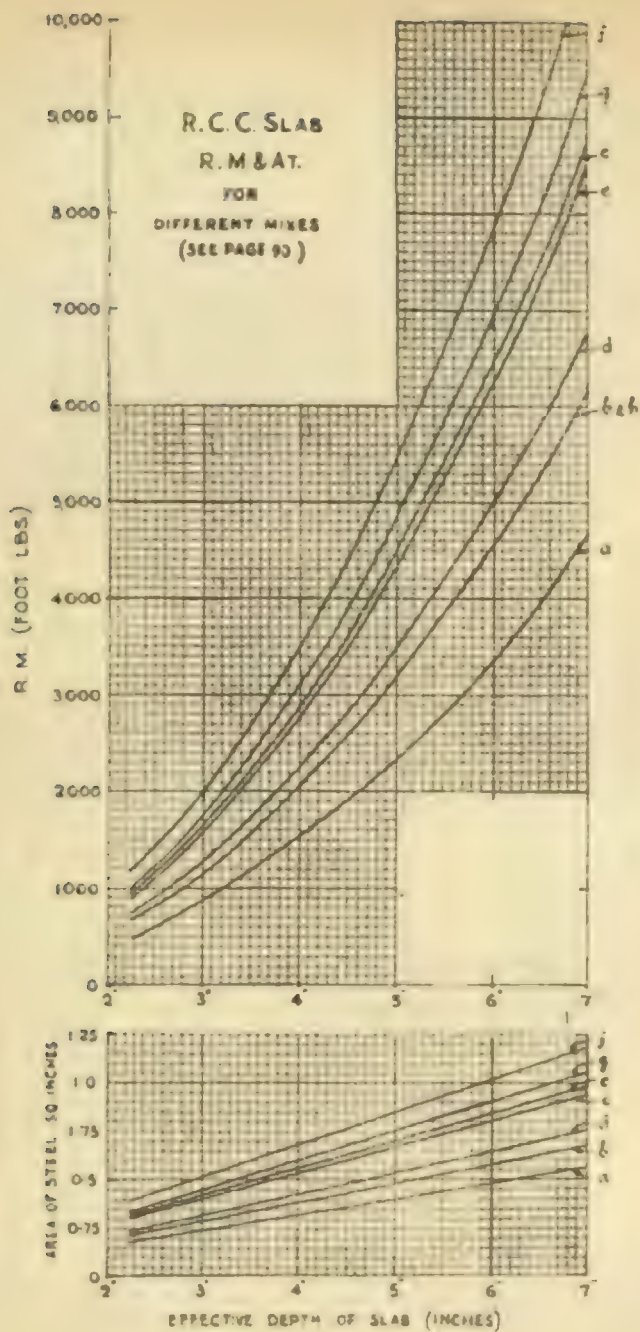
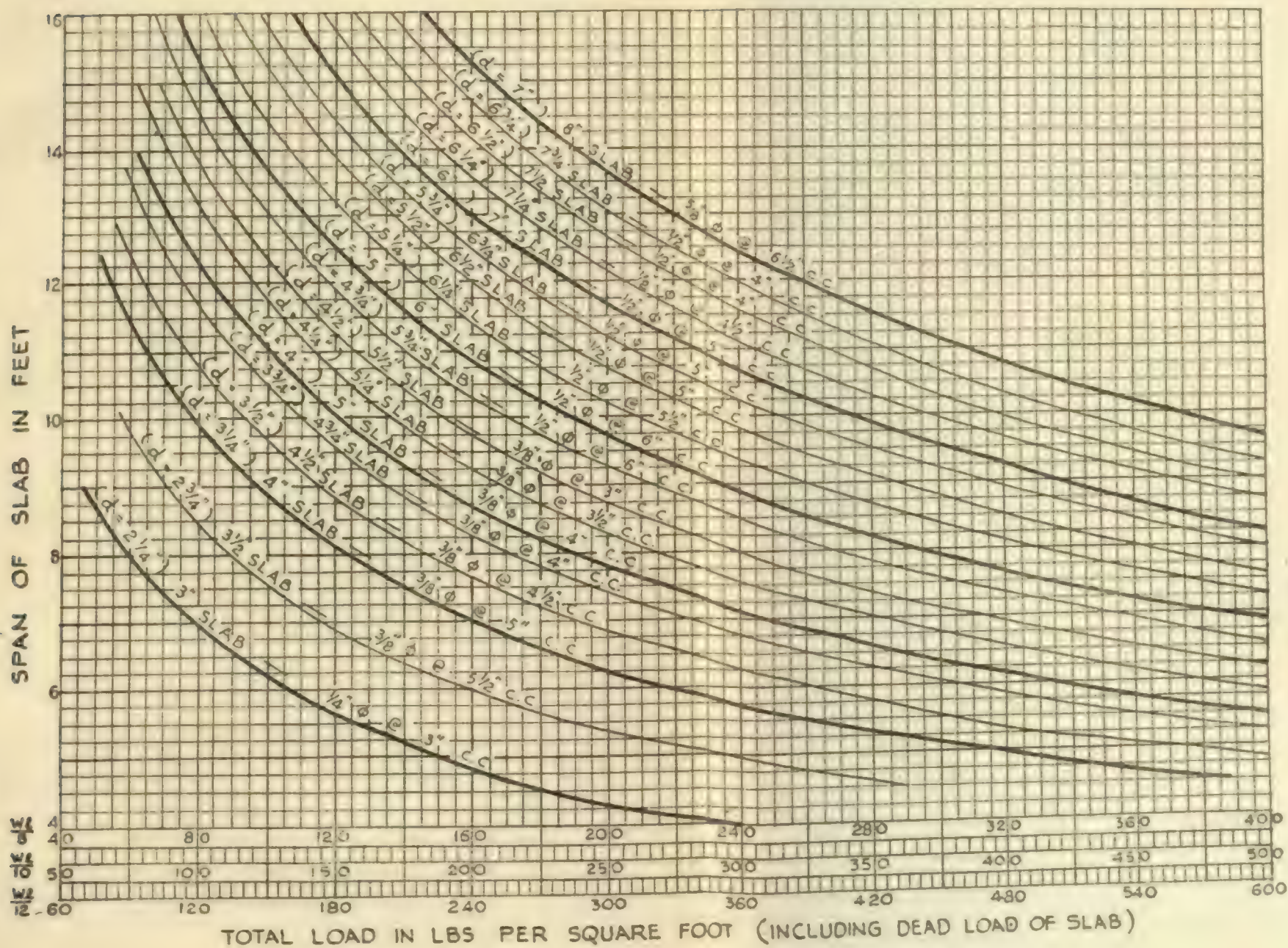
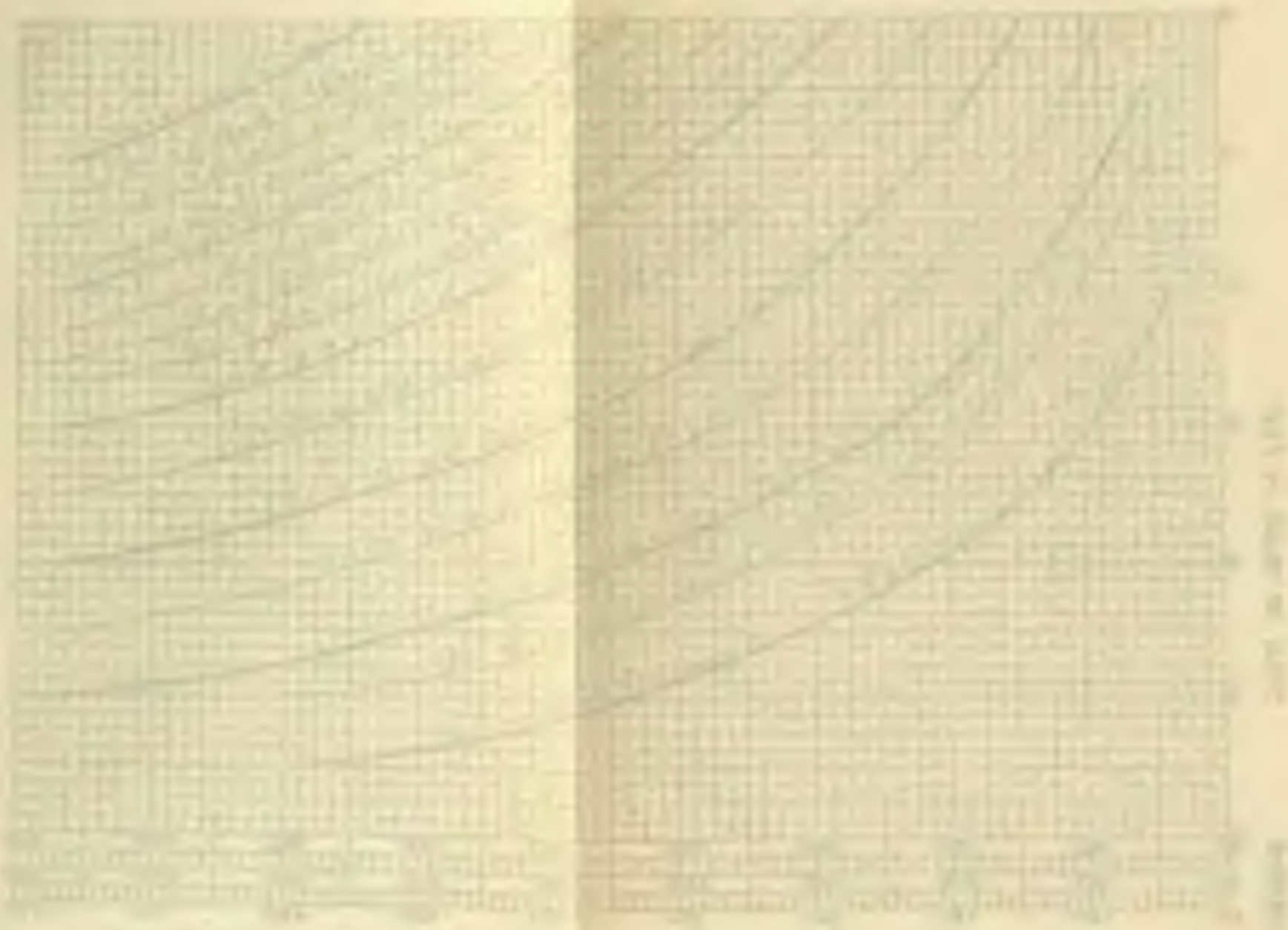


Chart 4.8.

DESIGN OF R C C FLOOR SLABS

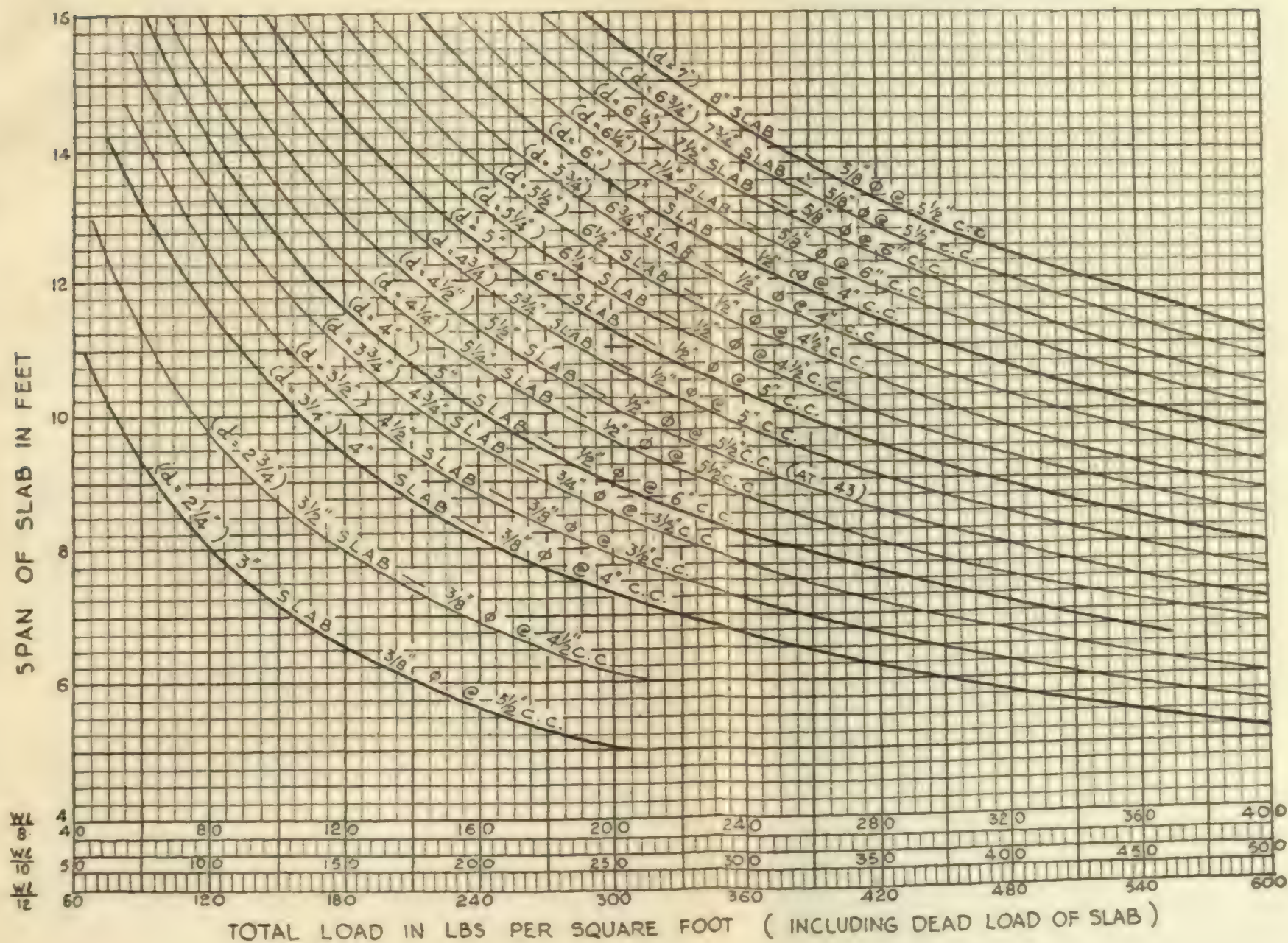
STRESSES: $f_c = 600$, $f_t = 16,000$ & $m = 15$





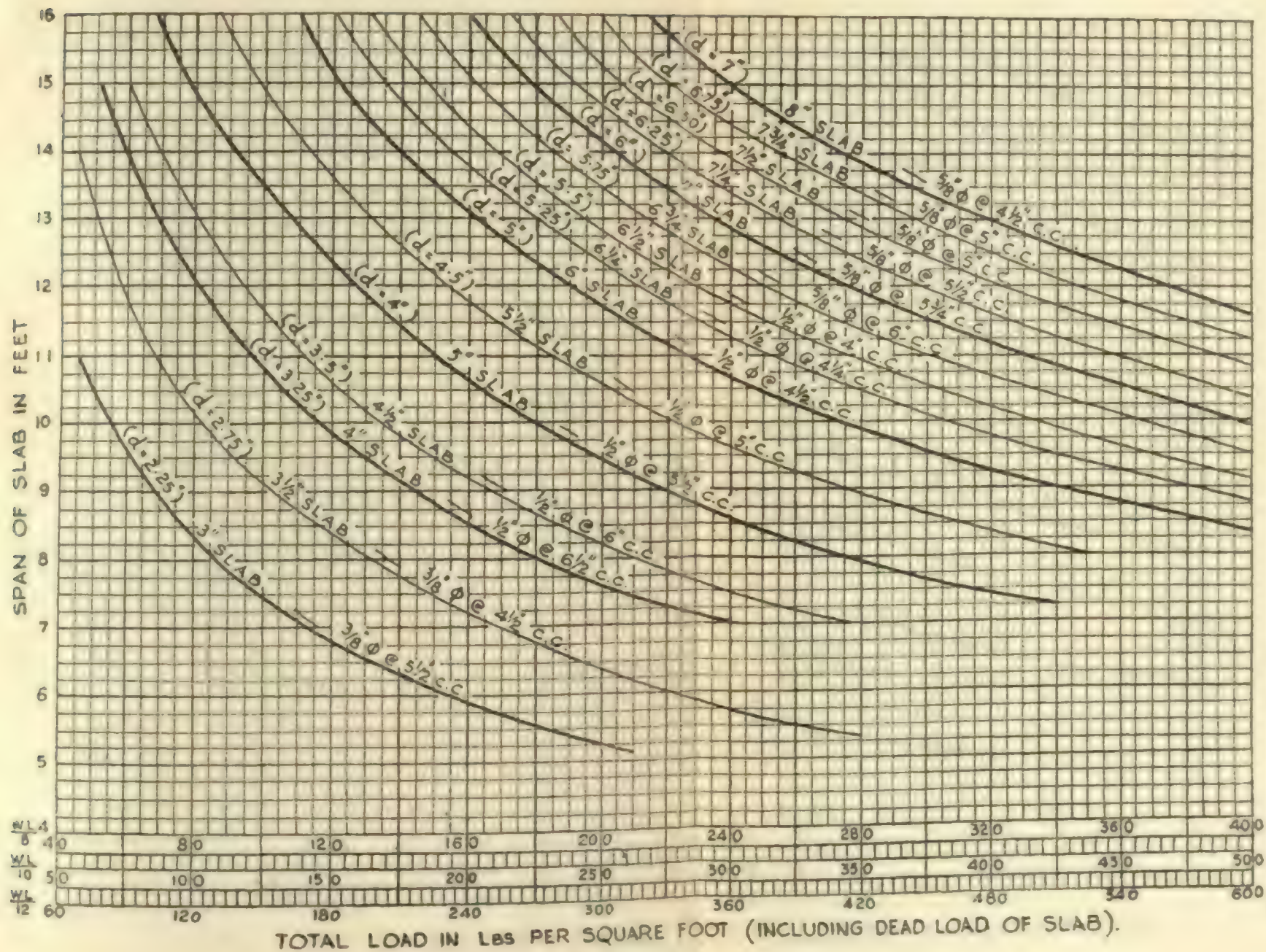
DESIGN OF R.C.C. FLOOR SLAB

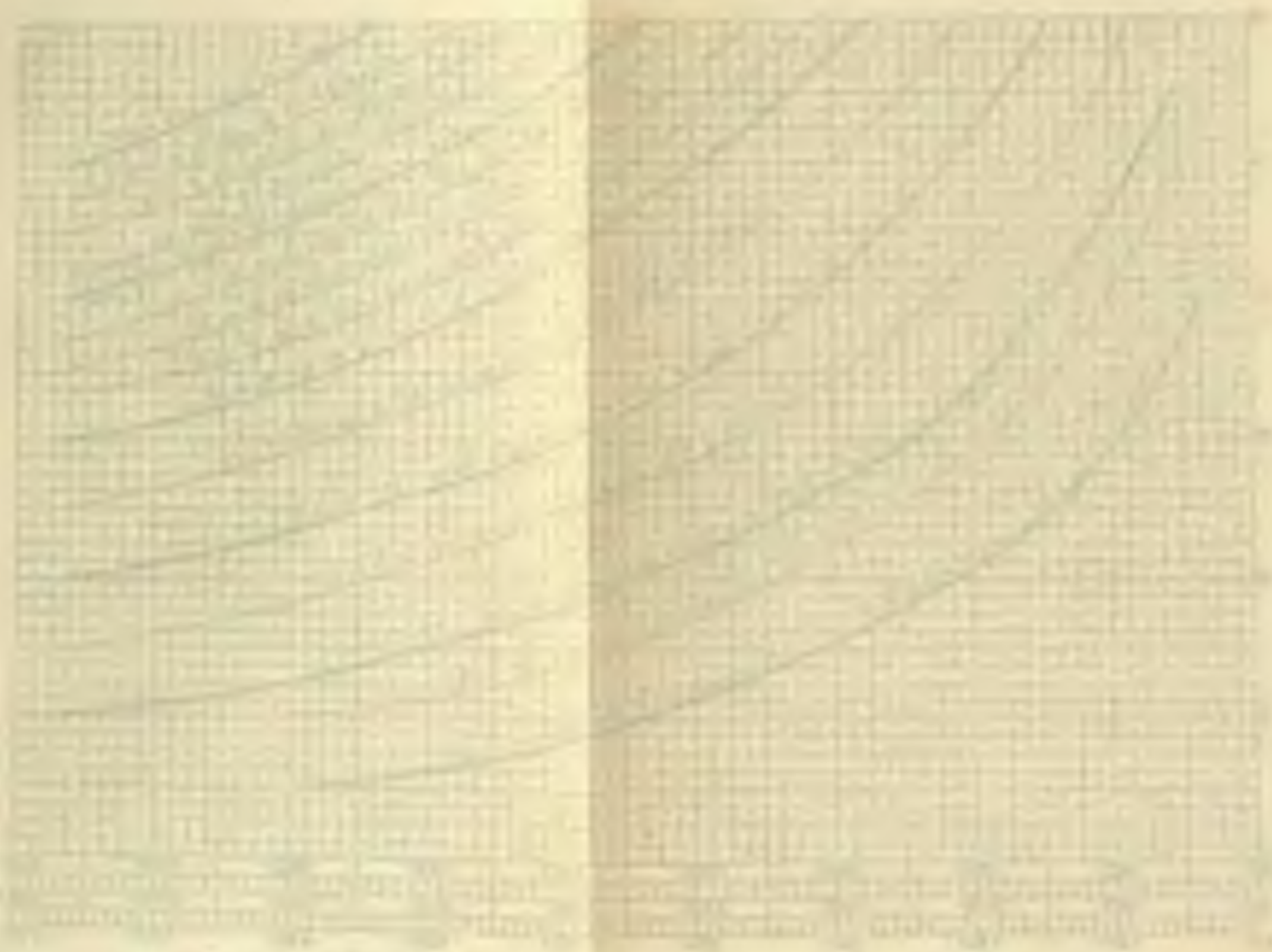
STRESSES: $C = 750$, $T = 18,000$ & $m = 13$



DESIGN OF R.C.C. FLOOR SLAB

STRESSES - $f_c = 750$. $f_t = 18,000$ & $m = 18$





The curves are labeled with 'C' and 'D' values, indicating different data series. The curves generally show an increasing trend as the x-value increases.

DESIGN OF R.C.C. SLABS

4.3 EXAMPLES ILLUSTRATING USE OF VARIOUS CHARTS AND TABLES IN THIS CHAPTER.

(1) Charts 4-1 & 4-2 and Table 4-a:

Find R.M. & At of a slab where stresses to be adopted are:

$$f_c = 550 \text{ lbs per sq. inch}$$

$$f_t = 16000 \text{ " " " "}$$

$$m = 15$$

$$f_t/f_c = 16000/550 = 29.$$

$$\therefore n = .34 \text{ from chart 4-1.}$$

$$\therefore j = 1 - n/3 = .867$$

$$\therefore \text{R.M.} = \frac{1}{2} f_c \times n \times j b d^2 = 550/2 \times .34 \times .87 b d^2 \\ = 83 b d^2$$

$$\& \text{At (from chart 4-2)} = .6\%$$

The same values can be obtained directly from table 4-a

(2) Charts 4-3 to 4-7:

Find R.M. of a slab, effective depth 5" and reinforced with.

(a) .3 sq. inches of steel (5/16" @ 3" c.c.)

(b) .6 —do.— (7/16" @ 3 1/2" c.c.)

and designed for $f_c = 750$ psi. $f_t = 18000$ psi & $m = 18$.

Case a

$$p = .3 \times 100/60 = .5\%$$

$$n \text{ (chart 4.3)} = .342$$

$$j = 1 - .342/3 = .885$$

$$\text{R.M.} = \text{At} \times f_t \times j d$$

$$.3 \times 18000 \times .885 \times 5 \text{ in. lbs.}$$

$$= 1950 \text{ ft. lbs.}$$

Case b

$$p = .6 \times 100/60 = 1.0\%$$

$$.445$$

$$1 - .445/3 = .852$$

$$f_c/2 \times n \times j \times b d^2$$

$$750/2 \times .445 \times .852 \times 12 \times 5^2$$

$$3500 \text{ ft. lbs.}$$

or (from chart 4-4)

$$Q = 77 \text{ bd}^2$$

$$= 77 \times 25$$

$$= 1925 \text{ ft. lbs.}$$

$$Q = 142 \text{ bd}^2$$

$$= 142 \times 25$$

$$= 3550 \text{ ft. lbs.}$$

or Direct from chart 4-7

$$1925 \text{ ft. lbs.}$$

$$3550 \text{ ft. lbs.}$$

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Chart 4-8 or Table 4-b.

Find R.M. & At for a slab (effective depth 6") designed as per B.S. Code with aggregates as per B.S. 882.

Refer table 4-b under "g" R.M.—6948 ft. lbs & At—.907

Refer chart No. 4-8 R.M.—6950 " " At—.900

Tables 4-c, 4-d, 4-e, etc. and

Charts 4-9, 4-10, 4-11 & 4-12.

are self explanatory giving

(a) safe load per sq. ft.

(b) other structural particulars

(c) quantities of steel and concrete per 100 s. ft.

for simply supported slabs designed for various values of f_c , f_t & m . For continuous and semi-continuous spans the safe loads may be increased by 50% and 20% respectively.

CHAPTER 5.
RECTANGULAR BEAMS

CONTENTS

- 5.1 Singly reinforced beams.
- 5.2 Beams with compressive reinforcement.

Charts & Tables.

CHAPTER 5

RECTANGULAR BEAMS

5.1 SINGLY REINFORCED.

The same formulæ as those for slabs apply to design of rectangular beams. However, in case of slabs, the concrete area is generally sufficient to meet the shear stresses, while in case of rectangular beams provision for shear stresses will have to be made by means of bent up bars and stirrups.

The charts and tables in this chapter are useful in designing rectangular beams ordinarily employed in practice. Continuous beams in a structure which are treated as T-beams in centre of span, behave as rectangular beams over supports and the charts can be used for their calculation by placing the required reinforcement at top.

Tables 5-a, 5-b and 5-c give M.R. & A_T for rectangular beams for different concrete and steel stresses.

Charts 5-1, 5-2 and 5-3 also give M.R. & A_T as above.

Tables 5-d, and 5-e give safe load per r.ft. for rectangular beams as above.

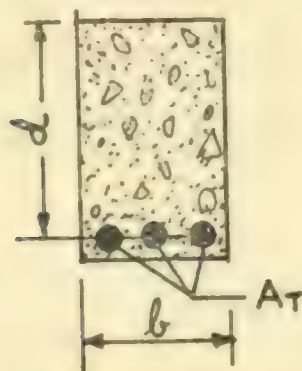


Fig. 5-1. Singly reinforced rectangular beams.

5.2 BEAMS WITH COMPRESSIVE REINFORCEMENT.

In practice, beams with compression steel have to be used in the following cases:

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- (a) T-beams, when continuous, behave as rectangular beams on support and when singly reinforced require considerable depth to take up the B.M. Steel for compression being automatically available from the two spans adjacent to a support, a doubly reinforced rectangular beam is more suitable from architectural considerations and practical reasons.
- (b) Rectangular beams, lintels, etc. where the depth is necessarily restricted from consideration of headway or other architectural reasons.
- (c) Braces, walls of storage reservoirs, etc. where B.M. reverses according to loading conditions.

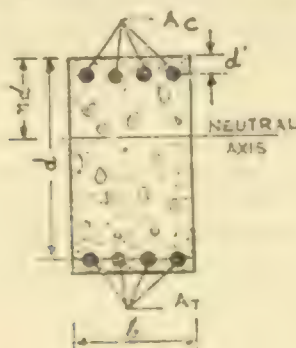


Fig. 5-2. Beam with compression reinforcement.

In case of (a) and (c), the following formulae give the amount of A_c and A_t in sq. inches for B.M. = M inch lbs.

$$A_c = \frac{M - 95 b d^2}{K_1 d} \quad \text{or} \quad \frac{M - 126 b d^2}{K_2 d}$$

$$A_t = .00675 b d + \frac{M - 95 b d^2}{16000 (d - d^1)} \quad \text{or} \quad .008 b d + \frac{M - 126 b d^2}{18000 (d - d^1)}$$

(Old L.C.C.) (New L.C.C.R.)

where K_1 or $K_2 = \frac{fs (m-1) (1 - \frac{d^1}{d}) (n - \frac{d^1}{d})}{m (1-n)}$

the values of fs being 16000 & 18000 and n being .36 & .385 in case of Old and New L.C.C.R. respectively and $m=15$. For both cases, the values of K_1 and K_2 are tabulated below:—

RECTANGULAR BEAMS

d^1/d	.02	.04	.06	.08	.10	.12	.14	.16	.18	.20
K_1	7780	7150	6570	5980	5450	4920	4410	3920	3440	2980
K_2	9620	9000	8280	7680	6960	6360	5760	5160	4560	4080

In case of (c), it is necessary to provide equal top and bottom steel. In this case, both steel and concrete may not be stressed to the maximum permitted stress. If steel is assumed to be stressed to the maximum permissible limit, the stress in concrete will be below the maximum limit. Alternatively if concrete is fully stressed, steel will be understressed. The following procedure is necessary to find out the R.M. of section reinforced with known amount of A_c and A_t :—

Determine position of neutral axis by the general formula

$$n = \sqrt{\{mr + (m-1)r^1\}^2 + 2\{mr + (m-1)r^1\} \frac{d^1}{d}} - \{mr + (m-1)r^1\}$$

where $r = \frac{A_t}{bd}$ and $r^1 = \frac{A_c}{bd}$

After the position of neutral axis is determined, the R.M. can be found by the following formulæ:—

$$\frac{M}{bd^2} = f_s \frac{n}{m(1-n)} \left[\frac{n}{2} \left(1 - \frac{n}{3}\right) + \frac{A_c}{bd} \left(1 - \frac{d^1}{d}\right) \left(n - \frac{d^1}{d}\right) \frac{m-1}{n} \right] = Q$$

or

$$\frac{M}{bd^2} = \frac{f_c}{2} n \left(1 - \frac{n}{3}\right) + \frac{A_c}{bd} \left(1 - \frac{d^1}{d}\right) \left(n - \frac{d^1}{d}\right) \frac{(m-1)}{n} f_c = Q$$

The smaller of the two values of Q calculated by the above formulæ to be adopted. The values of Q are given below for a few typical cases.

$$m=15$$

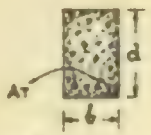
Max. permissible stresses	
$f_c =$	600 lbs. p.s.i.
$f_s =$	16000 lbs. p.s.i.
$A_c = A_t = 1\%$	141
1.5%	186
2%	221

Max. permissible stresses	
$f_c =$	750 p.s.i.
$f_s =$	18000 p.s.i.
	159
	232
	276

180,000
165,000
150,000
135,000
120,000
105,000
90,000
75,000
60,000
45,000
30,000
15,000
0

R.C.C. BEAMS RECTANGULAR BEAMS R.M & AT. FOR VARIOUS DEPTHS & WIDTHS

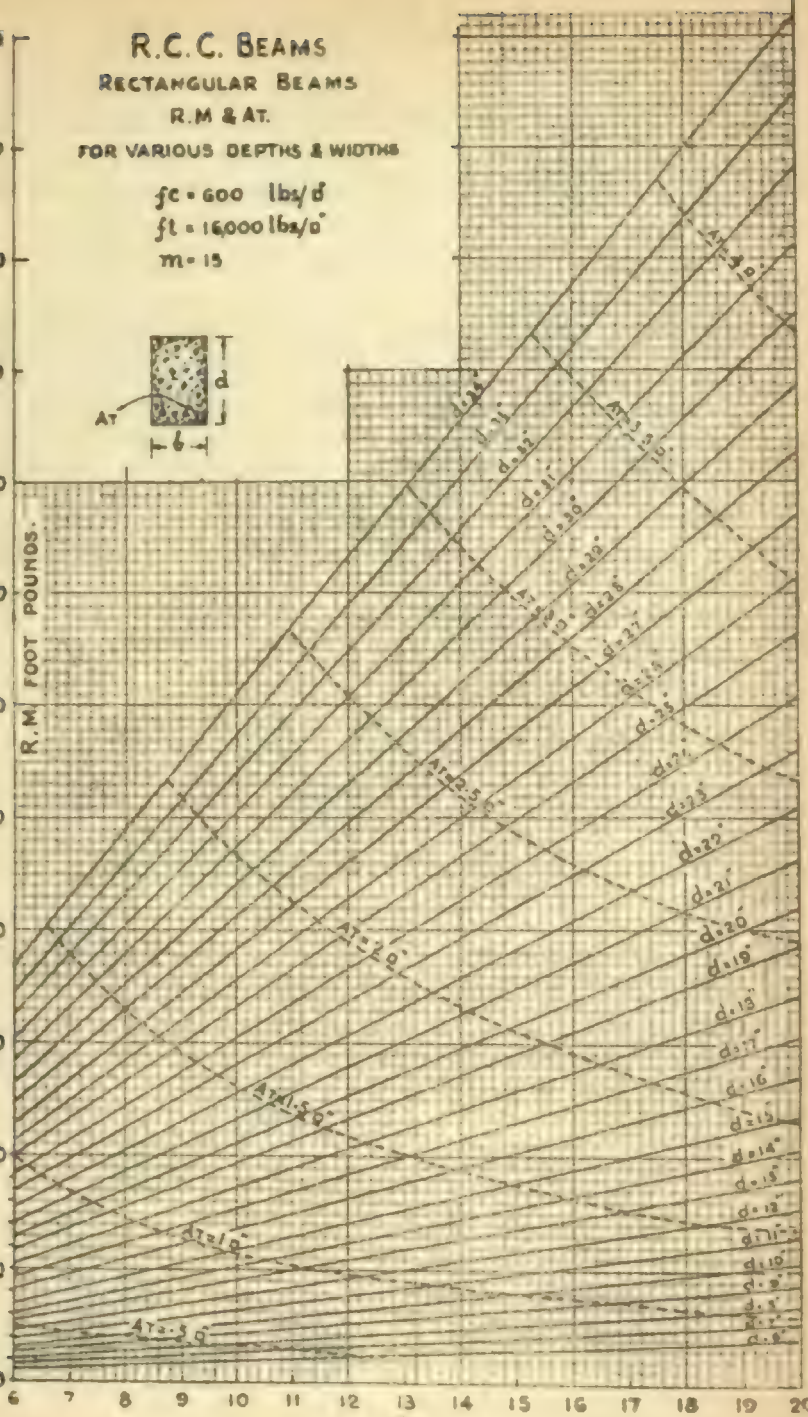
$f_c = 600 \text{ lbs/sq}$
 $f_t = 16,000 \text{ lbs/sq}$
 $m = 15$



R.M. FOOT POUNDS.

BREADTH "b" INCHES

Chart S-1.



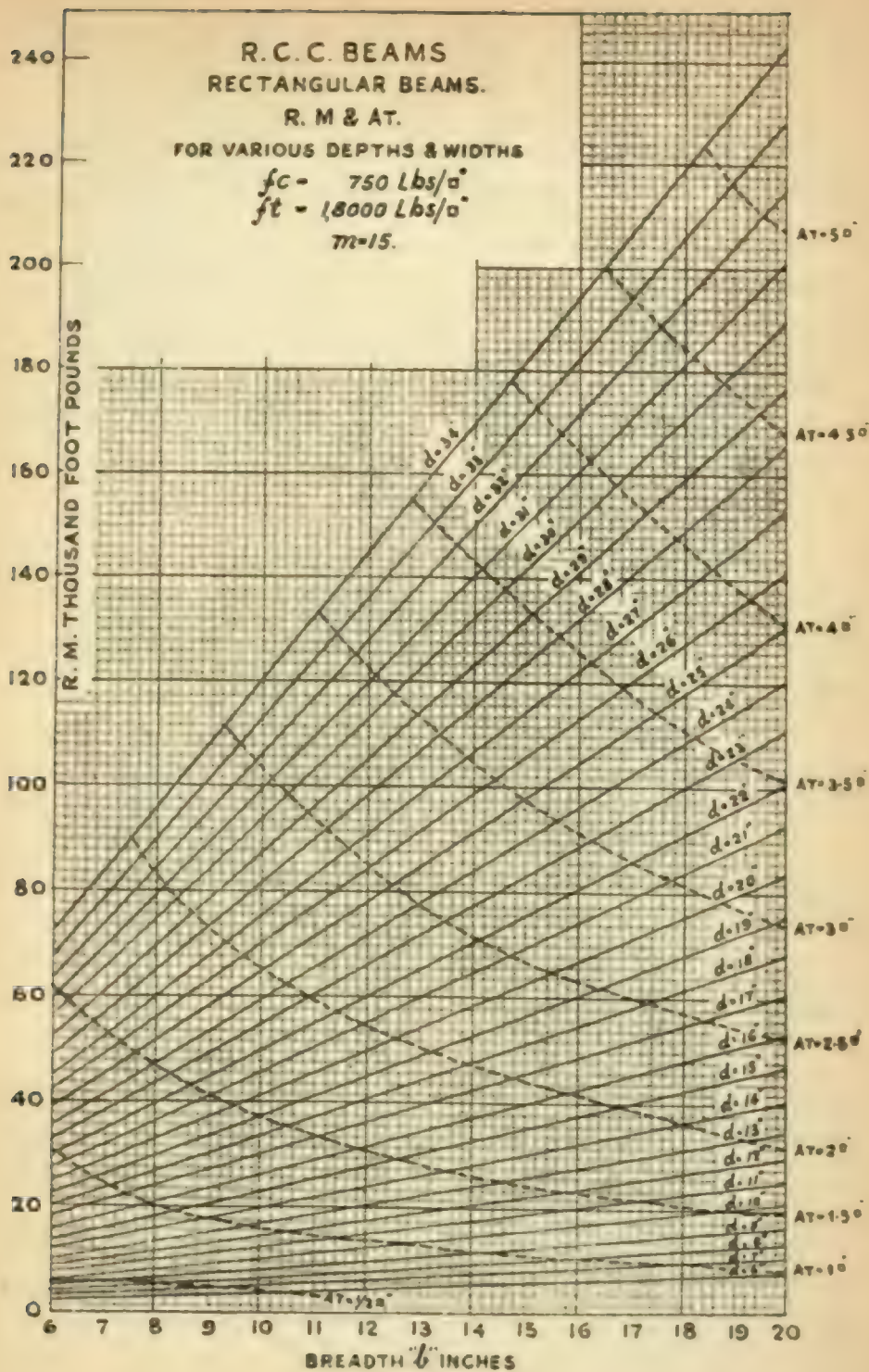


Chart 5-2.

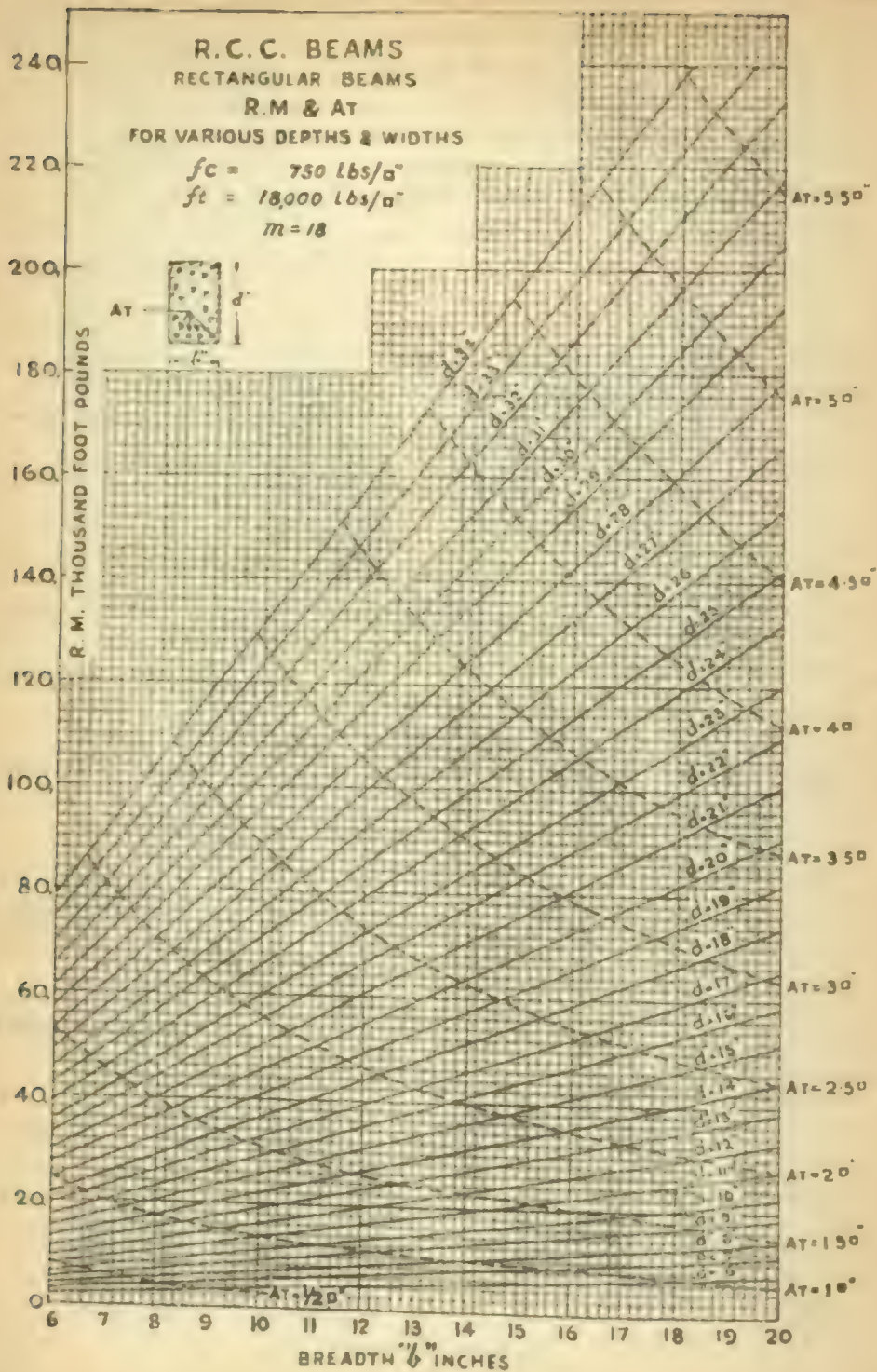


Chart 5-3.

Table 5-a. RECTANGULAR BEAMS R.M. & At for various depths & widths.

fc = 6000 ft = 16000 m = 15. R.M. in ft.lbs.

$\frac{h}{d}$	6"	8"	9"	10"	12"	14"	16"	18"	20"	
6"	1710 243	2250 322	2565 36	2850 41	3420 49	3990 57	4275 61	4560 65	5130 73	5700 81
7"	2927 28	3103 38	3491 42	3879 47	4655 56	5431 66	5819 71	6207 76	6982 86	7758 94
8"	3040 32	4053 44	4560 49	5070 54	6285 66	7095 76	7680 81	8167 86	9129 97	10133 108
9"	3847 36	5130 49	5771 55	6412 61	7695 73	8977 85	9619 91	10260 97	11542 109	12833 121
10"	4750 40	6333 54	7125 61	7916 68	9580 80	11083 95	11875 100	12667 106	14550 120	16568 135
11"	5747 44	7665 60	8621 67	9579 75	11495 88	13411 102	14379 111	15347 119	17242 133	19138 148
12"	6840 48	9129 65	10260 75	11400 82	13680 96	15660 113	17160 122	18240 130	20520 144	22800 162
13"	8027 52	10703 71	12041 79	13379 89	16055 106	18731 122	20069 131	21407 141	24683 156	26758 175
14"	9210 56	12413 76	13965 85	14717 94	18020 112	21723 132	23275 141	24827 151	27930 168	31033 189
15"	10667 60	14259 82	16031 91	17812 103	21376 120	24937 141	26719 151	28500 162	32062 181	35625 202
16"	12160 64	16213 87	18249 97	20266 108	24320 128	28373 150	30400 161	32427 173	36840 193	40581 216
17"	13727 68	18393 95	20591 103	22879 115	27465 136	32031 160	34319 171	36607 183	41162 205	45758 229
18"	15390 72	20320 98	23085 109	25650 121	30780 154	35910 170	38475 181	41040 194	46170 217	51500 242
19"	17147 76	22863 104	25721 115	28579 128	34295 156	40011 179	42868 191	45727 203	51460 230	57156 258
20"	19000 82	25333 109	28500 121	31667 135	36900 164	44333 188	47500 202	50666 216	57000 240	63333 270
21"	20947 86	27930 115	31421 127	34912 142	41878 172	48877 198	52369 212	55860 227	62845 252	69825 282
22"	22900 90	30625 120	34485 134	38317 149	45980 180	53643 207	57475 222	61307 238	69970 265	76980 299
23"	25127 94	33603 126	37691 140	41890 154	50265 188	58631 217	62818 232	67064 249	75982 277	83758 310
24"	27360 98	36480 131	41040 145	45600 163	54720 196	63840 226	68400 242	72960 259	82080 289	91200 322
25"	29687 102	39583 136	44198 151	49479 169	59375 204	69271 245	74219 262	79166 279	89682 300	98608 336
26"	32110 106	42913 142	48165 157	53516 175	64220 212	74923 245	80292 263	85667 281	98830 312	107080 350
27"	34627 110	46170 147	51941 163	57712 182	69255 220	80707 264	86569 272	92340 292	105882 325	115425 384
28"	37240 114	49653 153	55880 169	62955 188	74480 228	86893 264	93100 283	99317 302	111720 337	124133 376
29"	39947 120	53363 158	59921 175	66579 196	79895 240	93211 273	99864 292	106526 313	119842 348	133188 390
30"	42750 124	57065 164	64125 182	71250 202	85580 248	99730 282	106875 303	114080 323	128250 361	142500 405
31"	45687 128	60863 169	68471 188	76079 210	91295 256	106511 292	114119 312	121727 334	136942 373	152158 418
32"	48640 132	64863 173	72960 196	81667 217	97280 264	113493 303	121680 323	129707 345	146920 385	162733 430
33"	51727 136	68970 178	77591 202	86212 223	103155 272	120609 310	129319 332	137940 356	155182 398	172425 445
34"	54910 140	73213 184	82365 208	91517 230	109620 288	128123 320	137230 343	146427 367	164730 410	183000 458

Table 5-b. RECTANGULAR BEAMS R.M. & A_T for various depths & widths
 $f_c = 750 \text{ ft} = 18000 \text{ m} = 15$. R.M. in ft.lbs.

$\frac{b}{d}$	6"	8"	9"	10"	12"	14"	15"	16"	18"	20"
6"	2254 299	3414 394	3102 432	3780 480	4536 576	5292 67	5670 73	6048 77	6424 86	7560 92
7"	3067 238	4116 448	4436 504	5145 560	6174 672	7203 78	7717 84	8232 90	9261 1-01	10290 1-12
8"	4032 394	5376 512	6048 576	6720 640	7804 768	8404 90	10080 96	10752 1-02	12096 1-15	13440 1-28
9"	5103 432	6604 576	7654 648	8505 720	10206 864	11907 1-01	12767 1-08	13608 1-15	15300 1-30	17010 1-44
10"	6360 480	8400 640	9450 720	10500 800	12600 960	14700 1-12	15750 1-20	16800 1-28	18900 1-44	21000 1-60
11"	7623 528	10164 704	11434 792	12705 880	15286 1-056	15167 1-23	19057 1-32	20829 1-41	22669 1-58	25410 1-76
12"	9072 576	12096 768	13608 864	15120 960	18144 1-152	21164 1-34	22680 1-44	24192 1-54	27216 1-73	30240 1-92
13"	10647 624	14196 832	15970 936	17745 1-040	21294 1-248	24843 1-46	26617 1-56	28392 1-66	31941 1-87	35490 2-08
14"	12348 672	16464 896	18522 1-00	20580 1-12	24696 1-34	28812 1-57	30870 1-68	32928 1-79	37044 2-02	41160 2-24
15"	14175 72	18900 96	21262 1-08	23625 1-20	28338 1-44	32973 1-68	35437 1-80	37900 1-92	42525 2-16	47250 2-40
16"	16128 77	21506 1-02	24192 1-15	26880 1-28	32256 1-54	37632 1-79	40320 1-92	43008 2-05	48344 2-36	53760 2-56
17"	18207 82	24276 1-09	27310 1-22	30345 1-34	36414 1-63	42483 1-90	45517 2-04	48552 2-18	54621 2-48	60690 2-72
18"	20402 88	27216 1-15	30618 1-30	34020 1-44	40824 1-73	47628 2-02	51030 2-16	54432 2-32	61236 2-58	68040 2-88
19"	22743 93	30324 1-22	34114 1-37	37905 1-52	45486 1-82	53067 2-13	56857 2-28	60648 2-43	68229 2-74	75810 3-04
20"	25200 98	33600 1-28	37800 1-44	42000 1-60	50400 1-92	58800 2-24	63000 2-40	67200 2-56	76600 2-88	84000 3-20
21"	27783 1-01	37044 1-34	41674 1-51	46305 1-68	55566 2-02	64827 2-35	69457 2-52	74088 2-69	83349 3-02	92610 3-36
22"	30492 1-05	40656 1-41	45736 1-58	50820 1-76	60984 2-11	71148 2-48	76230 2-64	81312 2-82	91476 3-17	101640 3-52
23"	33327 1-10	44436 1-47	49900 1-66	55362 1-84	66654 2-21	77763 2-58	83317 2-76	88872 2-94	99981 3-31	111090 3-68
24"	36288 1-15	48384 1-54	54432 1-73	60480 1-92	72576 2-33	84672 2-69	90720 2-88	96768 3-07	108864 3-46	120960 3-84
25"	39375 1-20	52500 1-60	59062 1-80	65625 2-00	78750 2-40	91875 2-8	98437 3-08	105000 3-20	118125 3-60	131250 4-00
26"	42588 1-24	56784 1-67	63882 1-87	70980 2-08	85176 2-50	99372 2-91	106470 3-12	113568 3-33	127764 3-74	141960 4-16
27"	45927 1-30	61236 1-73	68890 1-94	76545 2-16	91854 2-59	107168 3-02	114817 3-24	122472 3-46	137781 3-89	153090 4-32
28"	49392 1-34	65856 1-79	74088 2-02	82320 2-24	98784 2-67	115248 3-14	123480 3-36	131712 3-58	148176 4-03	164640 4-48
29"	52983 1-39	70644 1-86	79474 2-09	88305 2-32	105966 2-78	123627 3-25	132457 3-48	141287 3-71	159949 4-18	178610 4-64
30"	56700 1-44	75600 1-92	85050 2-16	94500 2-40	113400 2-88	132300 3-36	141750 3-60	151200 3-84	170100 4-32	189000 4-80
31"	60448 1-49	80724 1-98	90914 2-23	100906 2-48	121086 2-96	141267 3-47	151357 3-73	161448 3-97	181628 4-46	200810 4-96
32"	64312 1-54	86016 2-05	96768 2-30	107520 2-56	129024 3-07	150528 3-58	161280 3-84	172032 4-10	193536 4-61	215040 5-12
33"	68303 1-58	91476 2-11	102910 2-38	114345 2-64	137214 3-17	160986 3-70	171570 3-98	182052 4-22	205821 4-75	226600 5-28
34"	72428 1-63	97104 2-18	109245 2-45	121380 2-72	145656 3-28	169932 3-81	182070 4-06	194208 4-35	218484 4-90	242760 5-44

Table 5-c. RECTANGULAR BEAMS R.M. & AT for various depths & widths.
fc = 750 ft = 18000 & m = 18. R.M. in ft.lbs.

b d	6"	8"	9"	10"	12"	14"	15"	16"	18"	20"
6"	2466 32	3287 43	3699 481	4127 521	4932 64	5743 75	6183 80	6675 85	7308 98	8254 1 07
7"	3333 37	4475 50	5034 58	5618 62	6713 75	7831 87	8391 94	8950 1 00	10089 1 12	11230 1 25
8"	4384 43	5845 57	6676 64	7338 71	8768 65	10229 1 00	10960 1 07	11690 1 14	13122 1 28	14613 1 42
9"	5548 48	7307 64	8322 72	9287 81	11097 96	12946 1 12	13871 1 20	14705 1 28	16643 1 44	18474 1 60
10"	6850 53	9133 71	10275 80	11466 89	13706 1 07	15983 1 25	17125 1 34	18266 1 42	20550 1 60	22833 1 78
11"	8288 59	11050 78	12432 88	13673 98	16577 1 18	19337 1 37	20721 1 47	22101 1 57	24865 1 76	27627 1 96
12"	9864 64	13151 85	14706 96	16511 1 07	19728 1 26	23015 1 45	24660 1 60	26303 1 71	29502 1 92	32679 2 14
13"	11576 69	15434 93	17364 1 04	19377 1 16	23153 1 39	27011 1 62	28941 1 74	30869 1 85	34729 2 08	38587 2 31
14"	13486 75	17900 1 00	20139 1 12	22473 1 25	26852 1 50	31326 1 74	33565 1 87	35801 2 00	40276 2 24	44732 2 49
15"	15412 80	20549 1 07	23118 1 20	25798 1 34	30423 1 60	35061 1 87	36811 2 00	41096 2 14	46237 2 40	51374 2 67
16"	17536 85	23380 1 14	26304 1 28	29352 1 42	35072 1 71	40916 1 99	43840 2 14	46760 2 28	52808 2 56	58452 2 85
17"	19706 91	26394 1 21	29694 1 36	33128 1 51	39593 1 82	46190 2 12	49361 2 27	52788 2 42	59589 2 72	66260 3 03
18"	22104 96	29590 1 28	33291 1 41	37149 1 56	44388 1 92	51764 2 23	55485 2 40	59181 2 56	66485 2 88	74296 3 20
19"	24728 1 02	32970 1 35	37092 1 52	41392 1 69	49457 2 08	57698 2 37	61821 2 54	65990 2 71	74677 3 04	82784 3 38
20"	27400 1 07	36382 1 42	41100 1 6	45984 1 76	54890 2 14	63932 2 49	68500 2 67	73064 2 85	82260 3 20	91278 3 56
21"	30208 1 12	40276 1 50	45312 1 68	50565 1 87	60417 2 34	70486 2 62	75521 2 60	80553 2 88	90825 3 26	101130 3 74
22"	33154 1 17	44203 1 57	49731 1 76	55485 1 98	65928 2 35	77357 2 74	82865 2 94	88407 3 13	99462 3 52	110511 3 99
23"	36242 1 23	48312 1 64	54354 1 84	60400 2 08	72473 2 48	84550 2 87	90591 3 07	96627 3 28	108799 3 69	120786 4 09
24"	39456 1 28	52606 1 71	59184 1 92	65757 2 16	78912 2 58	92062 2 99	98510 3 21	105212 3 42	118368 3 85	131516 4 27
25"	42812 1 34	57081 1 78	64218 2 00	71662 2 23	85625 2 67	99593 3 12	107031 3 34	114162 3 56	128437 4 01	142706 4 45
26"	46306 1 39	61730 1 85	69459 2 08	77510 2 31	92612 2 78	108045 3 24	115765 3 47	123478 3 70	138618 4 17	154351 4 63
27"	49936 1 44	66579 1 92	74904 2 16	83587 2 40	99673 2 83	116516 3 36	124841 3 61	133128 3 83	149809 4 33	166452 4 81
28"	53704 1 50	71602 1 99	80356 2 24	89893 2 49	107408 2 99	125306 3 49	134280 3 74	143265 3 99	161112 4 49	179010 4 98
29"	57608 1 55	76801 2 07	86412 2 32	96429 2 58	115217 3 10	134417 3 61	144024 3 87	153617 4 13	172825 4 62	192625 5 16
30"	61650 1 60	82197 2 14	92475 2 40	103194 2 67	123380 3 29	143847 3 74	154123 4 01	164394 4 27	184950 4 61	205497 5 34
31"	65828 1 66	87768 2 21	98742 2 48	110188 2 76	131657 3 31	153396 3 86	164571 4 14	175536 4 41	197465 4 97	219425 5 32
32"	70144 1 71	93521 2 28	105216 2 58	117411 3 03	140288 3 42	165665 3 99	175702 4 27	187043 4 56	210432 5 13	233609 5 70
33"	74596 1 76	99458 2 35	111894 2 64	124864 2 94	149193 3 52	174054 4 11	186491 4 41	198196 4 70	223789 5 29	246861 5 87
34"	79186 1 82	105577 2 42	118779 2 72	132546 3 03	158372 3 63	184763 4 24	197963 4 54	211154 4 84	237556 5 43	263649 6 06

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RECTANGULAR BEAMS

Table 5-d.

$f_c=600$ psi, $f_t=16000$ psi, $m=15$

Safe load uniformly distributed lbs/r.ft. including wt. of beam.

Beam Span	M.M. Ft. Lbs.	A1 Sq. in.	Effective Span in Feet									
			6	7	8	9	10	12	14	16	18	20
6" x 8"	4695	.42	305	695	507	400	324	224	165	127	103	81
8" x 10"	8082	.54	1405	1635	795	625	500	450	258	188	161	127
8" x 12"	1120	.65	2200	1485	1110	900	750	505	372	285	232	184
8" x 14"	12413	.75	2720	1092	1551	1205	892	677	506	388	311	248
8" x 16"	10212	.86	2600	2650	2025	1600	1295	958	657	507	412	324
8" x 18"	20510	.92		3540	2570	2032	1608	1135	836	642	522	410
8" x 20"	25302	1.08			3169	2500	2020	1400	1020	792	645	500
8" x 22"	26002	1.18				2950	2442	1690	1250	958	780	613
8" x 24"	30478	1.30					2919	2010	1485	1140	930	729
8" x 26"	42811	1.40					3420	2370	1740	1340	1110	886
10" x 10"	7920	.68	1760	1290	990	782	654	440	323	247	196	154
10" x 12"	11405	.86	2530	1800	1430	1125	912	692	465	356	281	228
10" x 14"	15916	.93	3380	2540	1950	1535	1240	862	634	485	380	310
10" x 16"	20295	1.08	4390	3120	2540	2000	1640	1130	860	621	500	405
10" x 18"	26948	1.20		4200	3200	2530	2220	1430	1045	800	634	515
10" x 20"	31095	1.30		5170	2600	2130	2530	1750	1292	990	782	635
10" x 22"	28315	1.45			4780	3780	3120	2120	1592	1195	945	766
10" x 24"	45597	1.60				4550	3780	2850	1860	1430	1130	992
10" x 26"	55014	1.73				5200	4550	2970	2180	1670	1330	1070
10" x 28"	62060	1.86					5200	3440	2540	1940	1540	1241

Size b x d	R.M. Ft. Lbs.	At Sq. In.	Effective Span in Feet									
			6	7	8	9	10	12	14	16	18	20
12" x 12"	15640	97	3200	2230	1700	1350	1080	760	558	427	338	274
12" x 14"	18620	1-13	4140	3040	2330	1840	1490	1035	760	581	460	372
12" x 16"	26320	1-30	5400	3960	3290	2400	1940	1350	990	760	609	486
12" x 18"	30780	1-46		5000	3840	3050	2450	1705	1255	960	756	616
12" x 20"	38000	1-62		6280	4750	3760	3040	2110	1550	1185	937	760
12" x 22"	45980	1-76			5750	4550	3680	2500	1875	1435	1135	920
12" x 24"	54720	1-94				5400	4370	3040	2230	1710	1350	1094
12" x 26"	64220	2-10					5130	3560	2620	2050	1580	1284
12" x 28"	74480	2-26						4140	3040	2330	1835	1490
12" x 30"	85500	2-42						4750	3480	2670	2119	1710

RECTANGULAR BEAMS

Table 5-c.

$f_c=750$ psi, $f_t=18,000$ psi, $m=15$

Safe load uniformly distributed lbs/r.ft. including wt. of beam.

Size b x d	R.M. Ft. Lbs.	At Sq. In.	Effective Span in Feet									
			6	7	8	9	10	12	14	16	18	20
8" x 8"	5376	-51	1195	880	672	532	439	295	219	168	133	107
8" x 10"	8400	-64	1870	1370	1050	830	672	466	343	262	207	168
8" x 12"	12000	-77	2680	1970	1512	1195	970	670	494	378	298	242
8" x 14"	16464	-90	3660	2690	2058	1630	1322	915	675	515	407	329
8" x 16"	21504	1-02	4770	3500	2688	2120	1730	1190	877	672	530	430
8" x 18"	27216	1-15	6050	4430	3402	2690	2180	1510	1110	850	670	544
8" x 20"	33600	1-28			4280	3320	2690	1865	1370	1050	830	672
8" x 22"	39976	1-41			4820	3850	3120	2160	1580	1240	962	780
8" x 24"	48384	1-54				4750	3870	2680	1980	1510	1190	968
8" x 26"	56764	1-66					4550	3150	2320	1760	1400	1135

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Size b x d	R. M. Pc. Lbs.	At Sq. In.	Effective Span in Feet.									
			6	7	8	9	10	12	14	16	18	20
10" x 10"	10600	1-8	2330	1710	1310	1025	840	724	625	518	429	310
10" x 12"	15120	1-96	2360	2460	1920	1490	1210	940	617	472	372	302
10" x 14"	20580	1-12	4570	2590	2340	2150	1945	1140	827	648	609	412
10" x 16"	26880	1-24	5300	4400	2360	2660	2180	1500	1100	810	697	628
10" x 18"	34020	1-44		2900	2250	3360	2720	1900	1390	1082	840	680
10" x 20"	42000	1-60			5250	4180	3360	2340	1720	1310	1029	840
10" x 22"	50820	1-76			8120	5020	4050	2810	2070	1545	1258	1016
10" x 24"	60480	1-92				5970	4840	3360	2470	1842	1490	1210
10" x 26"	70980	1-98					5970	3940	2900	2235	1785	1419
10" x 28"	82300	1-24						4590	3360	2570	2035	1656
12" x 12"	18140	1-18	4020	2960	2270	1790	1450	1008	740	566	447	363
12" x 14"	24690	1-34	5420	4020	3067	2430	1970	1370	1000	770	610	494
12" x 16"	32220	1-54	7160	5290	4032	3190	2580	1790	1321	1005	795	645
12" x 18"	40824	1-73		6670	5103	4030	3260	2390	1860	1375	1005	810
12" x 20"	50400	1-92			8300	4970	4500	3290	2050	1575	1240	1008
12" x 22"	60984	2-11				5005	4870	3370	2470	1900	1500	1220
12" x 24"	72576	2-30					5800	4010	2950	2270	1790	1461
12" x 26"	85176	2-49						4720	3470	2660	2100	1704
12" x 28"	98784	2-68						5470	4010	3090	2420	1978
12" x 30"	113460	2-89						6300	4620	3540	2800	2227

NOTE.—Shear Intensity more than 75 lbs./sq. in. to left of Vertical Line.

CHAPTER 6
DESIGN OF T-BEAMS, L-BEAMS, ETC.

CONTENTS

Standard T-Beam Tables.

Charts.



CHAPTER 6

T-BEAMS OR L-BEAMS

In practice in case of T-beams, the thickness of the table 't'



Stresses in a T-Beam.

is the same as the thickness of slab already calculated to span between the beams. The width of the slab (B) which is supposed to act as top flange of the beam cannot be determined theoretically but is assumed as:

	Old L. C. C. R	D.S.I.R. Code or I.S.I. Code B.S. Code or New L.C.C.R.
T beam	<u>effective span</u>	<u>effective span</u> ✓
	4	3
	or	or
	Distance between ribs	Distance between ribs ✓
	or	or
	$12t$	$12t + b$
L beams	$4t$	<u>effective span</u>
		6
		or
		$\frac{1}{2}$ Distance between ribs
		or
		$4t + b$

The practical procedure followed and formulæ used in design of T beams are therefore as follows:—

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t and B are known, the value of d the effective depth is assumed from practical and economical or architectural considerations. For smaller value of d the amount of tension steel is more, for bigger values of d it is less. The most suitable value of d will therefore depend upon the relative cost of steel and concrete and the following formula is sometimes used to find it approximately.

$$d = \sqrt{\frac{rm}{f_t b_r}} + \frac{1}{2}$$

m = B.M. in inch lbs.

$$r = \frac{\text{cost of 4.38 cwts. of steel}}{\text{cost of 1 cft. of concrete}}$$

when the value of d is assumed, the value of lever arm also requires to be assumed by judgment. This value will vary

from $d - \frac{t}{2}$ to $d - \frac{t}{3}$. In case of thin slab and deep beam, the

value will be nearer to $d - \frac{t}{2}$ and in case of thick slab and shal-

low beam, the value will be nearer to $d - \frac{t}{3}$.

Since slabs in buildings are rarely thicker than 6" we may say for practical purposes that the value of lever arm is say upto .95d for deep beams and .89d for comparatively shallow beams. On these assumptions the amount of tensile steel A_t can be found from charts 6-1 and 6-2.

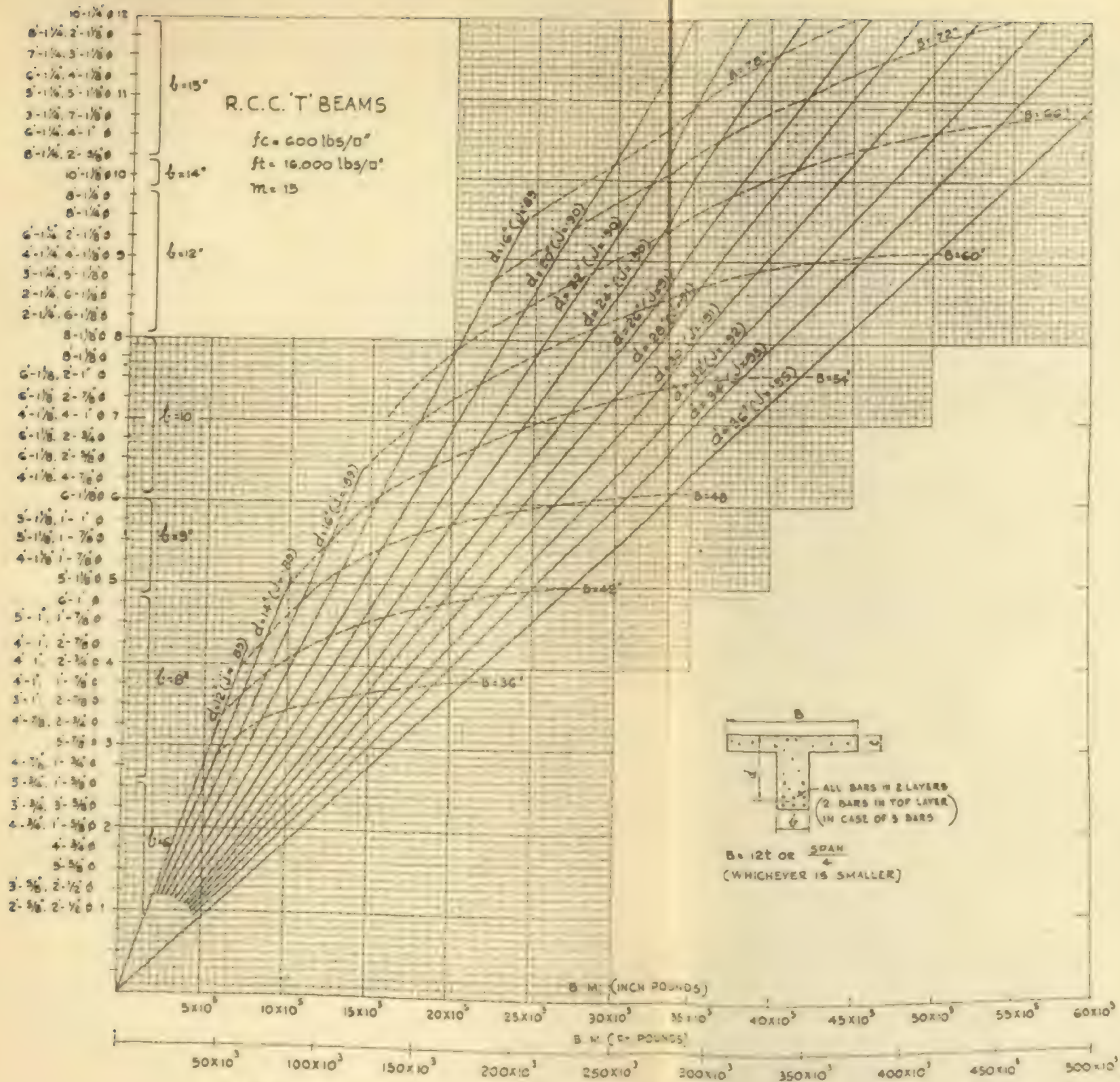
Value of lever arm $= d - \frac{t}{2}$ errs on the safe side and gives slightly more steel.

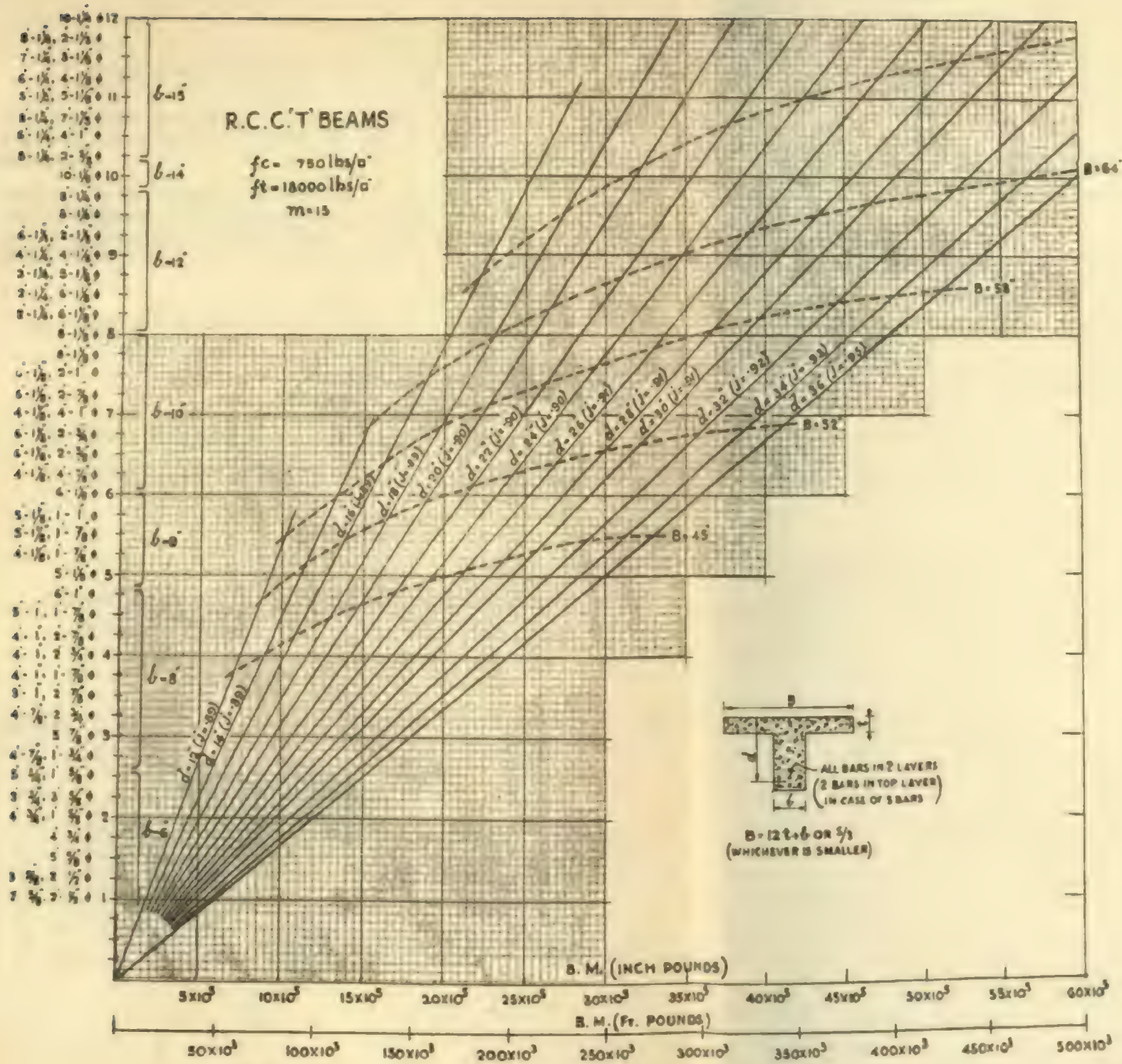
If further accuracy is required, charts Nos. 6-3, 6-4, 6-5 and table 6-a or formulae on the next page may be used, as follows:—

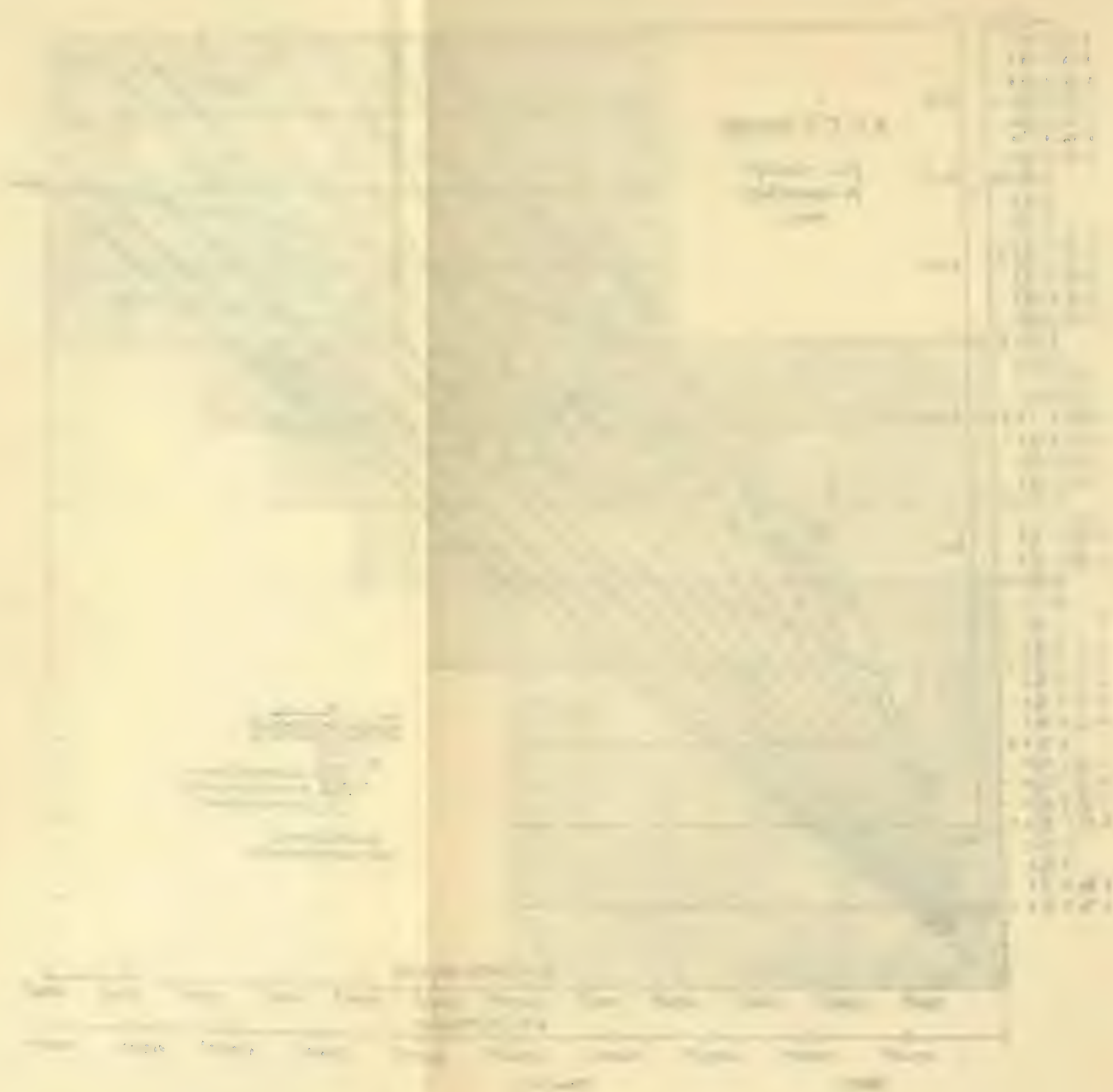
Find the value of $Q = \frac{M}{Bd^2}$ and ratio t/d .

Find from chart 6-3, 6-4 or 6-5 the f_c for the above values of Q & t/d . From chart No. 6-6 find the location of neutral axis for the particular value of f_c and the table 6-a will give the factor j for the particular value of n and t/d .

The maximum B.M. which a particular beam can take without causing excessive f_c is shown by the dotted lines in charts 6-1 and 6-2. Thus for a T beam with $d=36''$ and $B=60''$, the







DESIGN OF T-BEAMS OR L-BEAMS

B.M. should not exceed 50×10^5 inch lbs in chart 6-1. Otherwise f_c will be more than permitted and compression steel will be required.

Alternatively the following formulæ can be used for calculations of properties of T beams when approximate values of d and A_T are found from the charts No. 6-1 and 6-2 and the value of B is taken in conformity with code regulations.

$$(1) \text{ Position of neutral axis } nd = \frac{\frac{Bt^2}{2} + mA_T d}{Bt + mA_T}$$

$$n = \frac{1}{1 + (fs/mfc)}$$

$$(2) \text{ Value of lever arm } jd = d - \frac{1}{2} \cdot \frac{t^2}{6(2nd - t)}$$

$$(3) \text{ Moment of Resistance} = QBjd^2 \text{ in general}$$

$$= f_c \left(1 - \frac{t}{2nd}\right) Btjd \text{ on concrete}$$

$$= fs A_T jd \text{ on steel}$$

(Charts Nos. 6-3, 6-4 and table 6-a are based on the above formulæ and are drawn on basis of $fs = 16000$ or 18000 lbs/□" and $m = 15$.)

VALUES OF J

$n \backslash t/d$	.06	.08	.10	.12	.14	.16	.18	.20	.22	.24	.26	.28	.30	.32	.34	.36	.38	.40
.20	.97	.96	.96	.95	.94	.94	.93	.93										
.25	.97	.96	.95	.95	.94	.93	.93	.92	.92	.92								
.30	.97	.96	.95	.94	.94	.93	.92	.92	.91	.91	.90	.90	.90					
.35	.97	.96	.95	.94	.94	.93	.92	.91	.91	.90	.90	.89	.89	.89	.88			
.40	.97	.96	.95	.94	.93	.93	.92	.91	.90	.90	.89	.89	.88	.88	.87	.87	.87	.87
.45	.97	.96	.95	.94	.93	.93	.92	.91	.90	.89	.89	.88	.88	.87	.87	.86	.86	.85
.50	.97	.96	.95	.94	.93	.93	.92	.91	.90	.89	.89	.88	.87	.87	.86	.85	.85	.84
.55	.97	.96	.95	.94	.93	.92	.92	.91	.90	.89	.88	.88	.87	.86	.85	.85	.84	.84
.60	.97	.96	.95	.94	.93	.92	.92	.91	.90	.89	.88	.87	.87	.86	.85	.85	.84	.83

Table 6-a.

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STANDARD T-BEAMS.

The following tables, Nos. 6-b and 6-c, give particulars of simply supported T-beams carrying uniformly distributed load of 1000 to 3000 lbs. per running foot.

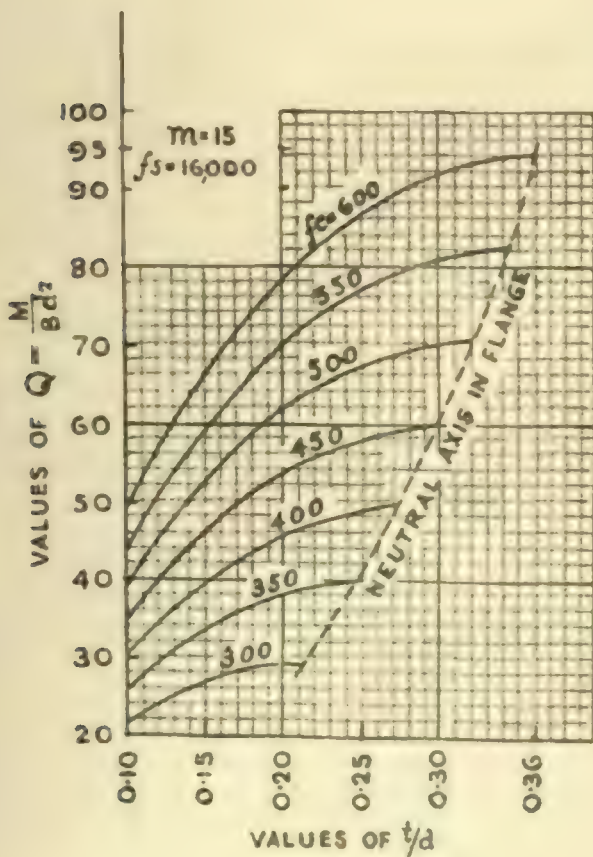


Chart 6-3.

DESIGN OF T-BEAMS OR L-BEAMS

D —Overall depth of beam in inches

b_r —Thickness of web " "

t —Minimum thickness of flange in inches necessary to keep compression below 600 or 750 lbs./sq. inch as permitted by regulations.

a, b, c, d main steel bars (a and c are in pairs)

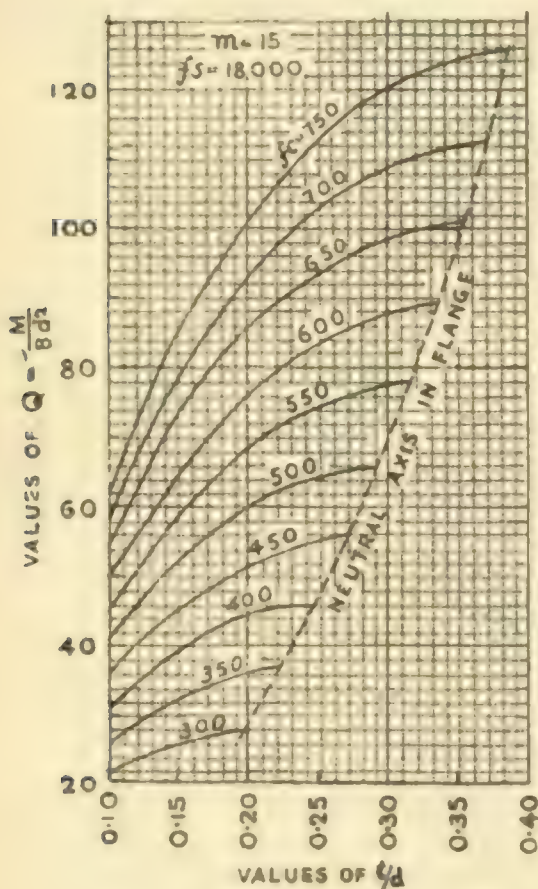


Chart 6-4

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K —distance in feet in which shear intensity exceeds 60 or 75 lbs. per sq. inch.—

n_1 number of stirrups in portion AB

n_2 —Do— BC

n_3 —Do— CD

n_4 —Do— DE

(Note: AB=BC=CD) in case of beam with 6 rods

(: AB=BC) Do. 5

These tables can be used for preliminary designs and for approximate estimates of quantities of concrete and steel.

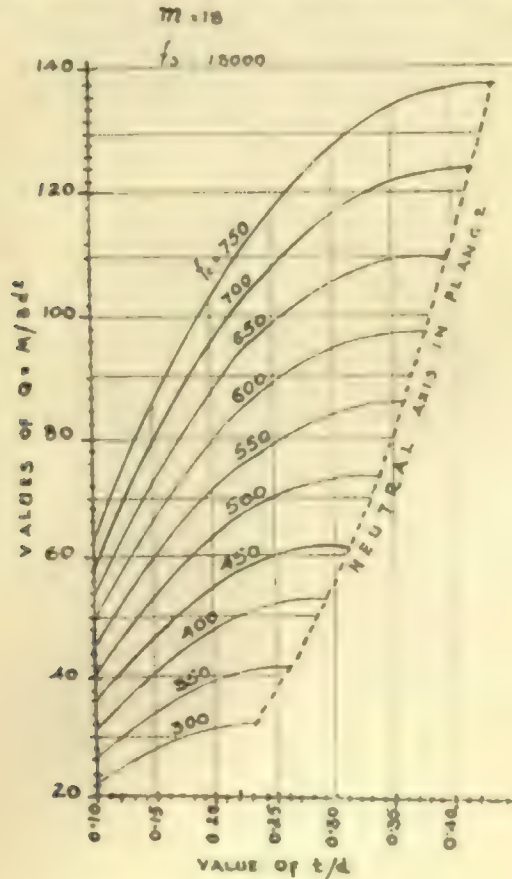


Chart 6-5.

Table 6-b. T-BEAMS. $f_c=750$ psi; $f_t=18000$ psi; $m=15$
 Span—8'-0" (effective). load—lbs. c.f.t. uniform including wt. of beam.

	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
SECTION	B ₁	B ₂	B ₃	B ₄	B ₅	B ₆	B ₇	B ₈	B ₉	B ₁₀	B ₁₁	B ₁₂	B ₁₃	B ₁₄
Main Steel Sq. Inches	.6	.7	.8	.8	1.0	1.1	1.2	1.3	1.53	1.53	1.90	1.67	1.9	1.9
a	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$
b	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$
c					$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$
d														
No. of $\frac{1}{2}$ " Strips	9	9	9	9	9	9	9	9	9	9	9	9	9	9
n ₁	1	1	1	1	1	1	1	1	1	1	1	1	1	1
n ₂	1	1	1	1	1	1	1	1	1	1	1	1	1	1
n ₃														
n ₄														
K				.25	.7	1.0	1.3	1.5	1.7	1.8	1.8	1.2	1.3	1.5
Concrete C.Ft.	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	5.1	5.1	7.7	7.7	7.7
Main Steel Lbs.	33	37	40	40	44	48	52	56	65	65	69	74	76	76
Strips Lbs.	10	10	10	10	10	12	12	12	12	12	12	12	12	12

Span—10'-0" (effective).

SECTION	B ₁	B ₂	B ₃	B ₄	B ₅	B ₆	B ₇	B ₈	B ₉	B ₁₀	B ₁₁	B ₁₂	B ₁₃	B ₁₄
Main Steel Sq. Inches	.8	1.2	1.22	1.31	1.5	1.67	1.9	2.1	1.9	1.94	2.1	2.21	2.3	2.53
a	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{2}$
b	$\frac{1}{2}$		$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$
c		$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
d														
No. of $\frac{1}{2}$ " Strips	10	10	10	10	11	11	13	13	13	13	13	15	15	15
n ₁	1	1	1	1	1	1	1	1	1	2	1	1	1	1
n ₂					1	1	2	2	2	1	2	2	2	2
n ₃												1	1	1
n ₄														
K			0.7	1.25	1.25	1.60	2.0	2.2	1.5	1.8	2.0	2.2	2.3	2.5
Concrete C.Ft.	5.5	5.5	5.5	5.5	6.3	6.3	6.3	6.3	6.4	6.4	6.4	6.4	6.4	6.4
Main Steel Lbs.	44	53	60	64	75	80	88	101	89	96	102	108	114	121
Strips Lbs.	11	11	11	11	12	12	14	14	14	14	14	16	16	16

Span=12'-0" (Effective)

load=lbs/r.ft. uniform including wt. of beam.

	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	MMB
SECTION	B ₁	B ₂	B ₃	B ₄	B ₅	B ₆	B ₇	B ₈	B ₉	B ₁₀	B ₁₁	B ₁₂	B ₁₃	B ₁₄
Main Steel sq. Inches	1.2	1.43	1.67	1.94	2.21	2.5	2.81	3.1	3.48	3.84	4.2	4.68	5.04	5.4
a	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
b	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$
c	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
d														
No. of $\frac{3}{8}$ " Strips	14	14	14	14	14	14	14	14	14	18	20	20	18	20
a ₁	1	1	1	1	1	1	1	1	1	1	1	2	1	2
a ₂	1	1	1	1	1	1	1	1	1	2	2	2	2	2
a ₃										1	2	1	1	1
a ₄														
K		4	1.2	1.8	2.2	2.6	1.0	2.2	2.5	2.6	3.0	2.4	2.8	2.6
Concrete C.F.	7.4	7.4	7.4	7.4	7.4	7.4	11.0	11.0	11.0	11.0	11.0	14.0	14.0	14.0
Main Steel Lbs.	68	76	90	100	117	123	121	128	143	153	160	162	162	170
Strips Lbs.	15	15	15	15	15	15	15	15	15	19	21	30	27	30

Span=14'-0" (effective).

SECTION	B ₁	B ₂	B ₃	B ₄	B ₅	B ₆	B ₇	B ₈	B ₉	B ₁₀	B ₁₁	B ₁₂	B ₁₃	B ₁₄
Main Steel sq. Inches	1.67	1.94	2.2	2.66	2.83	3.64	3.00	3.13	3.60	3.13	3.25	3.60	3.25	3.44
a	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
b	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$
c	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
d								$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
No. of $\frac{3}{8}$ " Strips	16	16	16	16	16	18	18	24	24	20	24	24	20	31
a ₁	1	1	1	1	1	1	1	1	1	1	1	1	2	2
a ₂	1	1	1	1	1	2	2	2	2	2	2	2	2	2
a ₃								1	1	1	1	1	1	2
a ₄								2	2		2	2	1	1
K		1.4	2.2	2.8	2.0	2.5	2.9	3.3	3.5	2.9	3.2	3.4	2.5	3.1
Concrete C.F.	8.6	8.6	8.6	8.6	12.7	12.7	12.7	12.7	12.7	16.1	16.1	16.1	17.8	17.8
Main Steel Lbs.	107	123	140	165	160	170	176	210	230	206	218	230	221	231
Strips Lbs.	17	17	17	17	18	20	20	26	28	20	30	30	24	30

Span=16'-0" (effective).

load=lbs/r.ft. uniform including wt. of beam.

	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
SECTION	B ₁	B ₂	B ₃	B ₄	B ₅	B ₆	B ₇	B ₈	B ₉	B ₁₀	B ₁₁	B ₁₂	B ₁₃	B ₁₄
Main Steel Sq. Inches	1.9	2.21	2.52	2.84	3.15	3.4	3.13	2.6	3.08	3.7	4.02	4.02	4.34	4.53
a	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	1	1	1	1	1	1
b	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	1	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	1
c	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	1	1	1	1
d					$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$
No. of $\frac{5}{8}$ " strips	17	17	17	18	20	20	20	20	24	18	24	24	30	30
a ₁	1	1	1	1	1	1	1	1	1	1	1	1	2	2
a ₂	1	1	1	1	2	2	2	2	2	2	2	2	4	4
a ₃				1	1	1	2	2	2	1	2	2	4	2
a ₄									2					2
K		1.25	2.2	3.0	3.6	4.0	3.2	3.6	4.0	2.4	2.6	2.2	3.4	3.7
Concrete C.F.T.	14.3	14.3	14.3	14.3	14.3	14.3	16.2	16.2	16.2	22	29	29	29	22
Main Steel Lbs.	107	164	184	204	234	254	240	260	284	271	300	300	320	333
strps. Lbs.	18	18	18	20	22	22	30	30	36	41	54	54	68	68

Span=18'-0" (effective).

SECTION	B ₁	B ₂	B ₃	B ₄	B ₅	B ₆	B ₇	B ₈	B ₉	B ₁₀	B ₁₁	B ₁₂	B ₁₃	B ₁₄
Main Steel Sq. Inches	2.3	2.84	3.15	3.4	4.0	4.0	4.16	4.53	4.84	4.53	4.72	5.14		
a	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	1	1	1	1	1	1	1	$1\frac{1}{2}$		
b	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	1	$\frac{5}{8}$	1	$\frac{5}{8}$	$\frac{5}{8}$	1	1	1		
c	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	1	1	1	1	1		
d			$\frac{5}{8}$	$\frac{5}{8}$	1	$\frac{5}{8}$	$\frac{5}{8}$	1	$\frac{5}{8}$	$\frac{5}{8}$	1	1		
No. of $\frac{5}{8}$ " strips	19	19	20	20	20	24	24	26	26	26	30	30		
a ₁	1	1	1	1	1	1	1	1	1	1	1	2		
a ₂	1	1	1	1	1	2	2	3	3	2	3	3		
a ₃			1	1	1	2	2	2	2	3	2	2		
a ₄				1	1	1	1	2	2	2	2	3		
K		1.3	2.4	2.4	4.0	3.3	3.6	4.2	3.5	3.9	4.2	4.5		
Concrete C.F.T.	16	16	16	16	16	21.5	21.5	21.5	26.8	26.8	26.8	22.8		
Main Steel Lbs.	186	223	243	277	303	309	323	352	348	350	372	403		
Strps. Lbs.	21	21	22	22	22	26	26	30	30	30	34	36		

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Span=20'-0" (effective).

load=lbs/r.ft. uniform including wt. of beam.

	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800
SECTION	B ₁	B ₂	B ₃	B ₄	B ₅	B ₆	B ₇	B ₈	B ₉	B ₁₀
Main Steel Sq. Inches	2.82	3.28	4.00	4.53	4.16	4.72	5.14	4.72	5.14	5.57
a	1	1	1	1	1	1	1 1/2	1	1 1/2	1
b	1	1	1	1	1	1	1	1	1	1 1/2
c	1	1	1	1	1	1	1	1	1	1 1/2
d	1	1	1	1	1	1	1	1	1	1 1/2
No. of #3 Strips	21	21	21	21	24	24	26	24	26	28
n ₁	1	1	1	1	1	1	1	1	1	1
n ₂	1	1	1	1	2	2	2	2	2	2
n ₃				1	1	2	2	2	2	2
n ₄						1	2		2	3
K	1	2.5	3.6	4.4	3.6	4.2	4.7	3.6	4.2	4.5
Concrete C.Ft.	17.7	17.7	17.7	17.7	22.3	22.3	22.3	20.5	20.5	22.3
Main Steel Lbs.	247	272	327	371	246	391	425	397	431	467
Stirrups Lbs.	23	23	23	23	26	26	29	24	26	33

Table 6-c. T-BEAMS. $f_c=600$ psi, $f_t=16000$ psi, $m=15$.
 Span=8'-0" (effective). load=lbs/r.ft. uniform including wt. of beam.

	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
SECTION	B ₁	B ₂	B ₃	B ₄	B ₅	B ₆	B ₇	B ₈	B ₉	B ₁₀	B ₁₁	B ₁₂	B ₁₃	B ₁₄
Main Steel Sq. Inches.	.59	.70	.81	.92	1.10	1.31	1.31	1.53	1.53	1.80	1.80	1.94	1.80	1.80
a	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈
b	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈
c								3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈
d														
No. of 1/2" Strps	8	8	10	10	11	11	12	12	12	14	15	17	15	15
n ₁	2	2	2	2	1	1	1	1	1	1	2	2	2	2
n ₂					1	1	1	2	2	2	2	2	2	2
n ₃							1	1	1	2	2	2	1	1
n ₄														
K			6	1.0	1.3	1.6	1.8	2.0	2.1	2.3	2.4	2.3	1.9	2
Concrete C.ft.	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	5.1	7.7	7.7
Main Steel Lbs.	33	37	40	43	52	56	56	64	64	74	74	79	74	74
Stirrups Lbs.	9	9	11	11	11	11	13	13	13	15	17	19	20	20

Span=10'-0" (effective).

SECTION	B ₁	B ₂	B ₃	B ₄	B ₅	B ₆	B ₇	B ₈	B ₉	B ₁₀	B ₁₁	B ₁₂	B ₁₃	B ₁₄
Main Steel Sq. Inches.	.92	1.31	1.31	1.53	1.72	1.94	2.07	2.21	2.07	2.24	2.29	2.65	2.65	3.41
a	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈
b	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈
c		3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈	3 ₈
d										3 ₈	3 ₈	3 ₈	3 ₈	3 ₈
No. of 1/2" Strps	11	12	12	12	12	12	16	16	16	20	20	22	22	24
n ₁	2	1	1	1	2	1	1	1	2	2	2	2	2	2
n ₂			1	1	1	1	2	2	1	2	2	2	2	2
n ₃						1	2	2	1	1	1	1	1	1
n ₄										2	2	2	2	4
K	.2	1.0	1.6	2.0	2.0	2.3	2.6	2.7	2.2	2.4	2.6	2.7	2.9	3.0
Concrete C.ft.	5.5	5.5	5.5	5.5	6.3	6.3	6.3	6.3	6.4	6.4	6.4	6.4	6.4	6.4
Main Steel Lbs.	49	67	67	65	80	92	99	104	101	107	111	125	125	134
Stirrups Lbs.	11	12	12	12	13	12	16	16	20	26	26	27	27	28

Span=12'-0" (effective).

load=lbs/r.ft. uniform including wt. of beam.

	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
SECTION	B ₁	B ₂	B ₃	B ₄	B ₅	B ₆	B ₇	B ₈	B ₉	B ₁₀	B ₁₁	B ₁₂	B ₁₃	B ₁₄
Main Steel Sq. Inches	1.42	1.67	1.92	2.21	2.42	2.68	2.90	2.72	2.90	3.02	3.28	3.28	3.44	4.00
a	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	1	$\frac{7}{8}$	1	$\frac{7}{8}$	$\frac{7}{8}$	1
b	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	1	$\frac{7}{8}$	$\frac{3}{8}$	1	1
c	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$
d												$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$
No. of $\frac{1}{2}$ " Strps.	12	12	12	12	12	14	17	17	17	20	22	22	22	22
n ₁	1	1	1	1	1	1	1	1	2	2	2	1	1	1
n ₂	1	1	1	1	1	1	1	2	2	1	2	2	2	2
n ₃					1	2	1	1	1	2	2	2	2	2
n ₄												2	2	2
K	1.6	1.5	2.2	2.7	3.0	3.3	2.7	3.0	3.2	3.4	3.6	3.1	3.3	3.5
Concrete C.Ft.	7.4	7.4	7.4	7.4	7.4	7.4	11.0	11.0	11.0	11.0	11.8	14.0	14.0	14.0
Main Steel Lbs.	79	89	103	116	125	139	143	143	154	159	178	155	200	225
Strps. Lbs.	14	14	14	14	14	15	16	16	16	21	24	20	22	26

Span=14'-0" (effective).

SECTION	B ₁	B ₂	B ₃	B ₄	B ₅	B ₆	B ₇	B ₈	B ₉	B ₁₀	B ₁₁	B ₁₂	B ₁₃	B ₁₄
Main Steel Sq. Inches	1.8	2.21	2.68	3.0	3.37	3.2	3.37	3.56	3.93	3.61	3.94	4.16	3.2	4.16
a	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$\frac{1}{2}$	$\frac{7}{8}$	$\frac{7}{8}$	1	1	$\frac{7}{8}$	1	1	1	1
b	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{8}$	$\frac{3}{8}$	$\frac{7}{8}$	1	$\frac{7}{8}$	1	1	$\frac{7}{8}$	$\frac{7}{8}$	1	$\frac{7}{8}$	1
c	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	1	$\frac{7}{8}$	1	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$
d										$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$
No. of $\frac{1}{2}$ " Strps.	15	16	16	21	15	14	20	22	25	23	26	26	22	26
n ₁	1	1	1	1	1	1	1	1	1	1	2	2	2	2
n ₂	1	1	1	2	1	1	2	2	2	2	2	2	2	2
n ₃			2	4	1	2	3	4	6	2	2	2	2	2
n ₄										4	5	5	5	2
K	1.6	1.5	3.1	3.6	3.0	3.1	3.7	4.0	4.1	3.7	4.0	4.1	4.2	4.4
Concrete C.Ft.	8.6	8.6	8.6	8.6	12.7	12.7	12.7	12.7	12.7	16.1	16.1	16.1	17.6	17.6
Main Steel Lbs.	120	142	166	180	188	202	214	225	247	240	263	274	260	281
Strps. Lbs.	16	16	17	23	16	17	20	22	28	26	32	32	63	66

Span=16'-0" (effective). load=lbs/r.ft. uniform including wt. of beam.

	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
SECTION	B ₁	B ₂	B ₃	B ₄	B ₅	B ₆	B ₇	B ₈	B ₉	B ₁₀	B ₁₁	B ₁₂	B ₁₃	B ₁₄
Main Steel Sq. Inches	2.1	2.41	2.76	3.24	3.65	4.02	4.37	4.16	4.54	4.71	4.53	4.71	5.14	5.04
a	$\frac{3}{8}$	$\frac{3}{8}$	1	1	1	1	1	1	1	1	1	1	1 $\frac{1}{2}$	1 $\frac{1}{2}$
b	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	1	$\frac{1}{2}$	1	1	1	1	1	1	1	1	1 $\frac{1}{2}$
c	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{1}{2}$	1	1	1	1	1
d					$\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{1}{2}$	1	1	$\frac{1}{2}$	1	1	1
No. of $\frac{1}{2}$ " Strps.	17	18	17	17	21	25	31	25	29	31	29	29	35	35
n ₁	1	1	1	1	1	1	1	1	1	1	1	2	2	2
n ₂	1	1	1	1	1	1	2	2	2	2	2	2	3	3
n ₃					1	1	2	2	2	2	2	2	3	2
n ₄					2	4	5	2	4	5	4	4	8	7
K	2.0	2.0	2.0	3.5	4.0	4.4	4.7	4.1	4.5	4.7	4.3	4.4	4.4	4.8
Concrete C.Ft.	14.3	14.3	14.3	14.3	14.3	14.3	14.3	18.2	18.2	18.2	20.0	20.0	20.0	20.0
Main Steel Lbs.	155	175	217	228	228	282	310	290	313	340	320	341	367	381
Strps. Lbs.	26	24	26	26	32	38	47	50	58	62	65	65	80	80

Span=18'-0" (effective).

SECTION	B ₁	B ₂	B ₃	B ₄	B ₅	B ₆	B ₇	B ₈	B ₉	B ₁₀	B ₁₁	B ₁₂
Main Steel Sq. Inches	2.49	3.01	3.61	4.16	4.71	4.16	4.53	5.13	4.65	5.34	5.70	5.96
a	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	1	1	1	1	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$
b	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	1	1	1	1	1	1	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$
c	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	1	$\frac{1}{2}$	1	1	1	1	1 $\frac{1}{2}$	1 $\frac{1}{2}$
d				$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$		1	$\frac{1}{2}$	1	1	1 $\frac{1}{2}$
No. of $\frac{1}{2}$ " Strps.	19	19	19	19	25	23	25	27	29	31	33	37
n ₁				1	1	1	1	1	1	2	1	2
n ₂				1	1	1	2	2	2	2	2	2
n ₃				1	1	1	1	2	2	2	2	2
n ₄				1	2	5	2	4	5	6	9	9
K	1.8	2.0	3.0	4.5	5.0	4.4	4.6	5.2	5.3	5.4	5.8	6.0
Concrete C.Ft.	16.0	16.0	16.0	16.0	15.4	19.0	19.0	19.0	22.2	22.2	22.2	22.2
Main Steel Lbs.	214	237	294	334	360	342	377	420	417	446	487	502
Strps. Lbs.	33	29	29	29	38	33	50	54	65	70	75	84

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Span=20' (effective).

load=lbs/r.ft. uniform including wt. of beam.

	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
SECTION	B ₁	B ₂	B ₃	B ₄	B ₅	B ₆	B ₇	B ₈	B ₉	B ₁₀	B ₁₁	B ₁₂	B ₁₃	B ₁₄
Main steel Sq. Inches	3.13	3.81	4.53	4.99	4.71	5.38	5.79	6.0	6.1	6.7				
a	7 ₈	1	1	1 ₈	1	1 ₈	1 ₈	1 ₈	1 ₈	1 ₈	1 ₈	1 ₈	1 ₈	1 ₈
b	7 ₈	1	1	1 ₈	1	1 ₈	1 ₈	1 ₈	1 ₈	1 ₈	1 ₈	1 ₈	1 ₈	1 ₈
c	7 ₈	1	1	1	1	1	1 ₈	1 ₈	1	1 ₈				
d	7 ₈	1	1	1	1	1	1	1 ₈	1	1 ₈				
No. of 1/2" Stairs	19	19	21	25	23	23	27	29	25	29				
a ₁	1	1	1	1	1	1	1	1	1	2	2			
a ₂	1	1	1	1	2	2	2	2	2	2	2			
a ₃	1	1	1	1	1	2	2	1	2	2				
a ₄			2	4	3	4	4	6	8	10				
K	2.8	4.0	4.9	5.5	4.9	5.4	5.8	5.7	6.1	6.4				
Concrete C.Ft.	17.0	17.0	17.0	17.0	21.0	21.0	21.0	24.5	24.5	24.5				
Main Steel Lbs.	262	316	372	401	401	462	489	515	516	573				
Stirrups Lbs.	29	29	32	38	35	46	54	60	70	88				

NOTE:

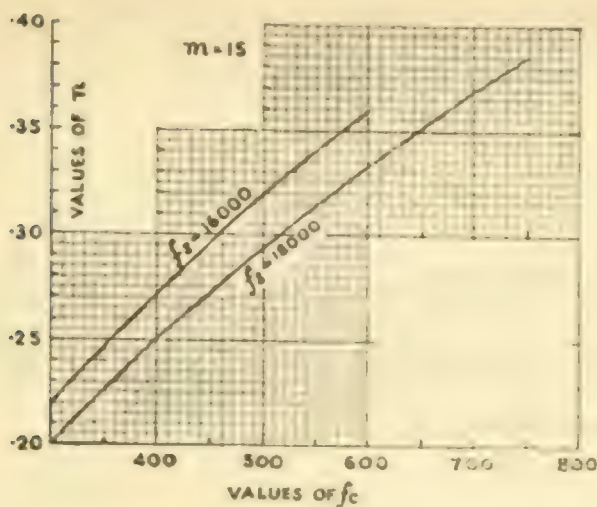
- Bearing assumed=D-1 inches.
- Quantities should be considered approximate. They are given on basis of: Total length of Beam=Effective Span + (D-1)' & t=4". The quantity of concrete is in web only. Steel includes anchor bars also.

Standard sections of T-beams used in Table Nos. 6-b & 6-c.

(all figures show inches)

	B ₁	B ₂	B ₃	B ₄	B ₅	B ₆	B ₇	B ₈	B ₉	B ₁₀
D	13	13	16	16	16	19	19	19	22	22
b	8	9	10	10	10	10	10	10	10	12
t	3	3	3	4	4 $\frac{1}{2}$	3	4	4 $\frac{1}{2}$	4 $\frac{1}{2}$	3

DESIGN OF T-BEAMS OR L-BEAMS



Example:—

Find the section of a simply supported T-beam 18' effective span carrying a load of 1600 lbs. per running foot.

From Chart 6-2:

$$\begin{aligned}
 M &= \frac{1600 \times 18^2}{8} = 64800 \text{ ft. lbs.} \\
 &= 65 \times 10^3 \text{ „ (say)} \\
 \text{for } d &= 14' \quad A_T = 4 \text{ sq inches.}
 \end{aligned}$$

From tables 6-b:

section reqd. = B_1 i.e. $16' \times 10'$

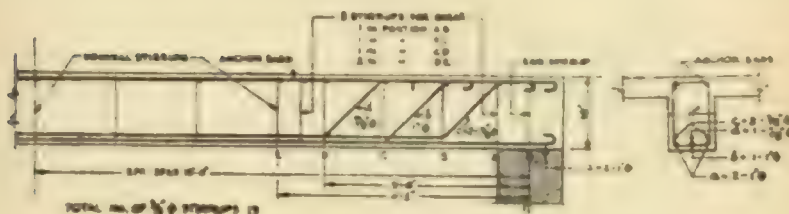
$A_T = 4.16 \square'$ i.e. $3-1''c$ & $3-\frac{7}{8}''c$

shear steel will be required for a distance of 4.5 ft. from the support and 5 stirrups of $\frac{7}{8}''c$ will be required in this portion.

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The whole beam will require 19 stirrups. The sketch below gives all the details of the beam.

($f_c=600$) psi, $f_t=16000$ psi and $m=1.5$)



CHAPTER 7

S H E A R

CONTENTS

7.1 General.

7.2 Examples.

Table No. 7a	}	Shearing resistance of inclined bars.
Table No. 7b		

Table No. 7c	}	Distance from support requiring shear reinforcement.
Table No. 7d		

Table No. 7e	}	Shearing resistance of stirrups spaced at various distances.
Table No. 7f		

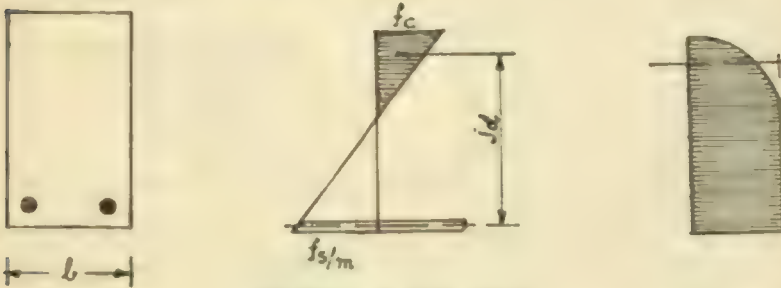
Chart 7-1 Spacing of stirrups.

CHAPTER 7

S H E A R

7.1 GENERAL

The shear intensity can be considered as uniform over the area bjd of a concrete beam.



Distribution of Shear Stress.

The shear stress therefore is $\frac{S}{bjd}$ lbs/sq inch.

when S is the vertical shear in lbs., b and d are breadth and depth of beam in inches, respectively.

This stress must not exceed $\frac{f_c}{10}$ otherwise separate shear reinforcement is necessary. If the intensity exceeds $\frac{3f_c}{10}$ it is necessary to enlarge the section of the beam.

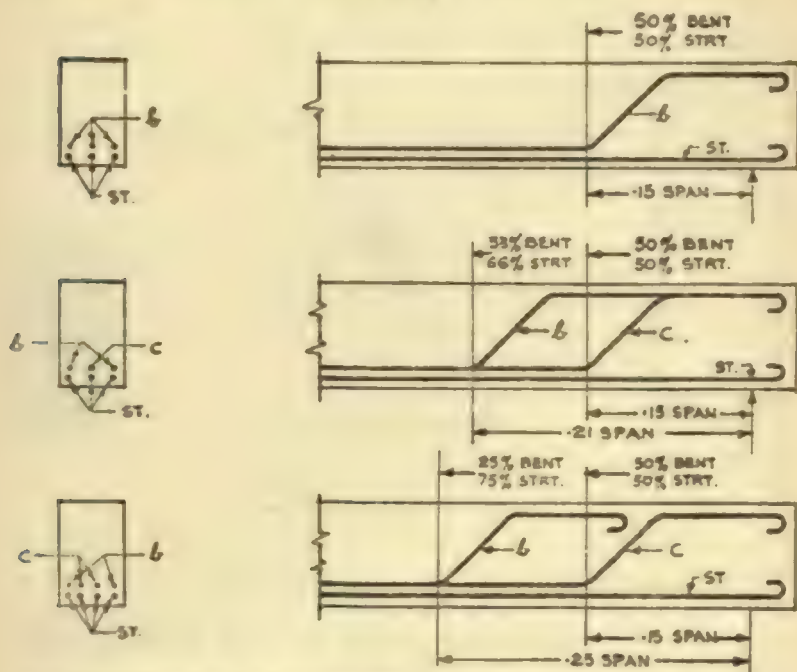
Provision for shear is made generally by:

- (a) Inclined bars.
- (b) Vertical stirrups.

(a) In ordinary practice special inclined bars are not provided but bars which form the tensile reinforcement are bent up to take shear in such portions of the beam where due to reduction of the bending moment they are no longer necessary for the tensile stress. The points where tensile bars can be bent up are found by drawing the B.M. diagram to scale, on which tensile value of each bar can be sketched to scale.

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The following sketches give the location of the point at which part of the tensile steel can be bent up, in case of uniformly distributed load on a simply supported beam.



NOTE:—ALL BARS ARE OF SAME DIAMETER.

Bending of bars for Shear.

The shearing resistance of inclined bars is given in Tables 7-a and 7-b. The distance from support of an uniformly loaded simply supported beam, for which shear steel is required for a particular shear intensity at support is given in Tables 7-c and 7-d.

(b) If the vertical binders are spaced at a distance p , there will be $\frac{jd}{p}$ number of binders in a length equal to lever arm of the beam. Then the shear resistance in this portion which is $\frac{Aftjd}{p}$ equals the shear S (A is the area of both the vertical arms of stirrup). The values of $\frac{Aft}{p}$ for different sizes and

(Continued on page 151)

R. C. C. BEAMS. STIRRUP SPACING CHART.

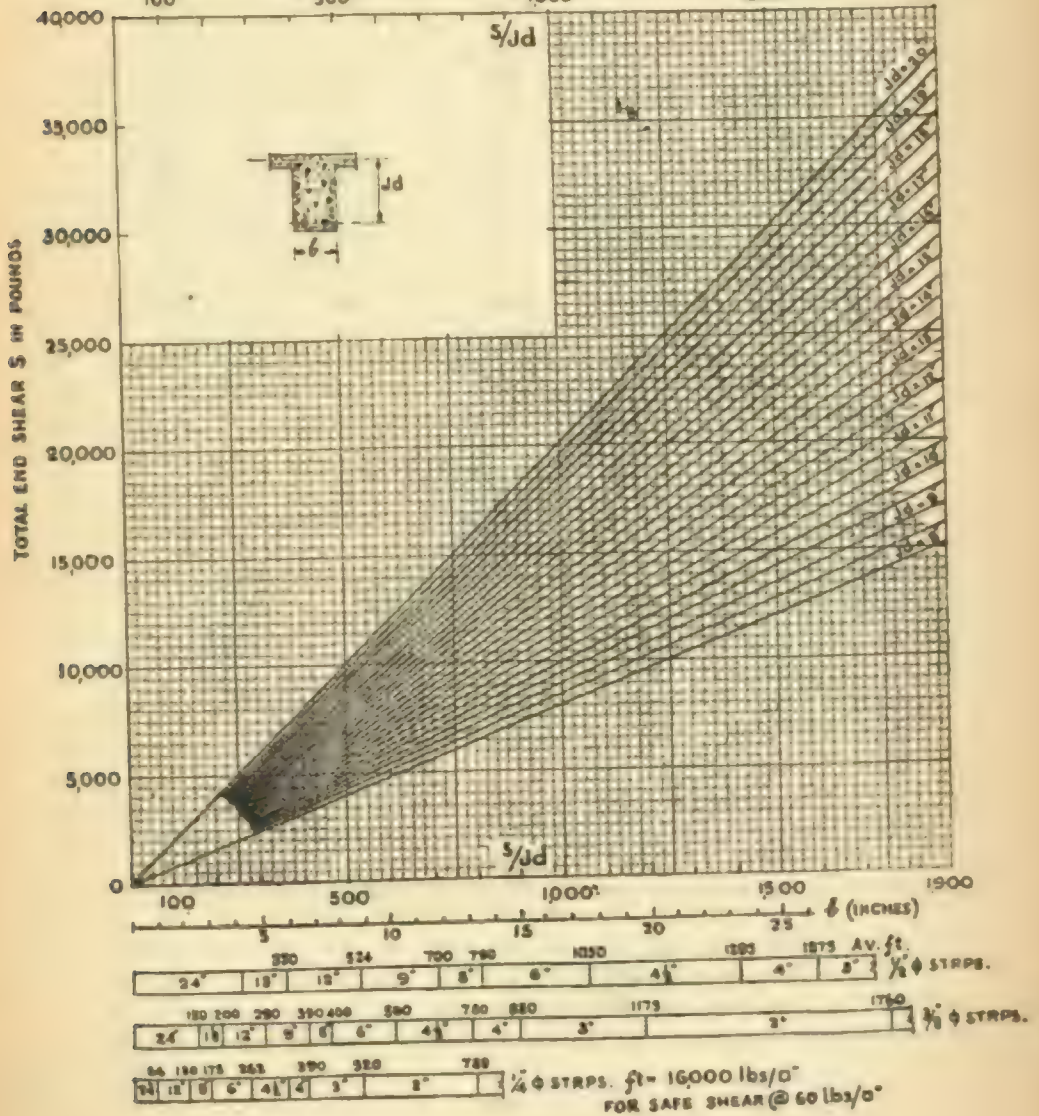
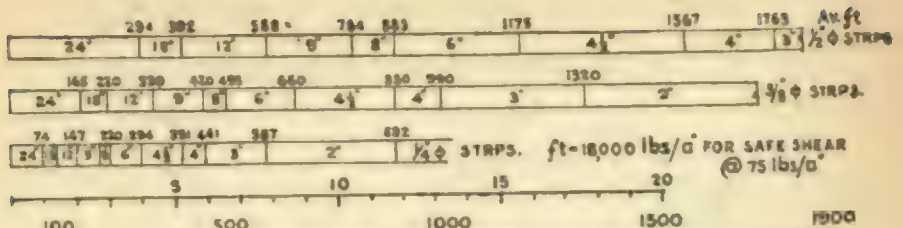


Chart 7-1.

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SHEAR RESISTANCE OF INCLINED BARS

Table 7-a.

Table 7-b.

Diameter of Bar	ft.=16000 Lbs./ft. ²		ft.=18000 Lbs./ft. ²	
	$\theta=45^\circ$	$\theta=30^\circ$	$\theta=45^\circ$	$\theta=30^\circ$
1/2"	2220	1575	2400	1750
5/8"	2470	1740	2670	1950
3/4"	2800	2000	3000	2200
7/8"	3200	2300	3400	2500
1"	3680	2600	3880	2850
1 1/8"	4240	2950	4440	3250
1 1/4"	4880	3350	5080	3700
1 1/2"	5600	3800	5800	4200
1 3/4"	6400	4300	6600	4750
2"	7280	4850	7480	5350

Table 7-c.

Diameter of Bar	VALUES OF $\frac{S}{b d}$ Ls. A ft./p.										ft.=16000 Lbs./ft. ²			
	2"	3"	4"	4 1/2"	5"	6"	7"	7 1/2"	8"	9"	10"	12"	15"	18"
1/4"	782	522	392	348	314	262	224	208	195	175	150	104	88	88
5/16"	1225	817	618	543	480	406	350	327	306	273	204	163	136	102
3/8"	1760	1175	880	783	706	587	505	470	440	391	293	235	196	147
1/2"	2430	1600	1200	1065	958	806	698	645	605	524	410	350	302	231

Table 7-d.

ft.=18000 Lbs./ft.²

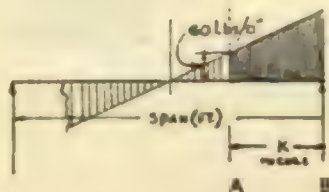
Diameter of Bar	2"	3"	4"	4 1/2"	5"	6"	7"	7 1/2"	8"	9"	10"	12"	15"	18"
1/4"	882	587	441	391	355	294	252	235	221	196	147	117	99	74
5/16"	1396	924	693	616	554	462	396	370	347	306	231	185	154	115
3/8"	1980	1320	990	880	792	660	566	528	496	440	350	284	230	165
1/2"	2730	1800	1360	1212	1080	906	774	715	670	580	472	392	324	241

Table 7-c.

Distance along beam span requiring shear steel (for safe shear at 60 lbs. per sq. inch.)

Note:—Figures tabulated give value of "k" in inches.

Sp Vn.	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
200	42	46.4	50.4	54.4	58.4	63	67.2	71.4	75.7	79.7	84	88.2	92.4	96.4	100.1
195	41.5	45.6	49.8	54	58.2	62.3	66.5	70.6	74.6	78.7	83	87.2	91.3	95.5	99.6
190	41	45.2	49.2	53.2	57.4	61.5	65.6	69.8	74	77.9	82	86.1	90.2	94.3	98.4
185	40.5	44.6	48.6	52.8	56.7	60.8	64.8	68.9	73	77	81	85	89.1	93.2	97.2
180	40	44	48	52.1	56	60	64	68	72	76	80	84	88	92	96
175	39.5	43.4	47.3	51.4	55.2	59.1	63.2	67	71	75	79	83	87	91	94.7
170	39	42.8	46.6	50.6	54.3	58.2	62.2	66.0	70	74	78	82	85	89.6	93.4
165	38	41.8	45.8	49.7	53.4	57.2	61.1	64.6	68.8	72.2	76	79.8	83.6	87.5	91.2
160	37.5	41.3	45	48.8	52.5	56.1	60	63.7	67.5	71.3	75	77.8	81.5	85.3	90
155	37	40.5	44.2	47.8	51.5	55.4	59.0	62.5	66.2	70.2	74	78.8	81.4	85	88
150	36	39.7	43.2	46.8	50.4	54	57.7	61.2	64.8	68.4	72	75.6	79.2	83	86.4
145	35	38.8	42.2	45.7	49	52.4	56.3	59.5	63	66.5	70	74.6	77	80.5	84
140	34.3	37.8	41.2	44.6	48	51.4	54.8	58.2		66.1	68.4	72	75.5	79	82.4
135	33.4	36.7	40	43.4	46.6	50	53.3	56.5	60	63.4	66.7	70	73.4	76.8	80
130	32.5	35.5	38.8	42	45.2	48.5	51.7	54.8	58.2	61.4	64.6	68	71.2	74.4	77.8
125	31.5	34.3	37.5	40.6	43.7	46.8	50	53.2	56.3	59.4	62.4	65.5	68.7	71.9	75
120	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72
115	29.7	31.5	34.4	37.2	40.2	43	46	48.6	51.5	54.4	57.4	60.2	63	65.8	68.7
110	27.3	30.1	32.8	35.5	38.2	41	43.7	46.3	49.2	51.8	54.6	57.4	60	62.8	65.6
105	25.7	28.3	30.9	33.5	36	38.6	41.2	43.6	46.4	48.8	51.5	54	56.7	59.2	61.8
100	24	26.4	29.6	31.2	33.4	36	38.4	40.6	43.2	45.7	48	50.5	52.8	55.2	57.7
95	22	24.2	26.4	28.6	30.8	33	35.2	37.4	39.4	41.6	44	46.2	48.4	50.6	52.8
90	20	22	24	26	28	30	32	34	36.0	38	40	42	44	46	48
85	17.6	19.4	21.5	23	24.7	26.4	28.2	30.5	31.7	33.4	35.2	37	38.6	40.5	42.3
80	15	16.5	18	19.5	21	22.5	24	25.5	27	28.5	30	31.5	33	34.5	36
75	12	13.4	14.4	15.6	16.8	18	19.2	20.4	21.6	22.8	24	25.2	26.4	27.6	28.8
70	8.5	9.4	10.4	11.2	12	12.8	13.7	14.5	15.4	16.2	17.1	18	18.7	19.7	20.5
65	4.6	5.1	5.6	6	6.5	7	7.4	7.8	8.25	8.6	9.1	9.76	10.2	10.7	11.1
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0



$$2k = \frac{\text{SHEAR AT SUPPORT}}{b \cdot d}$$

Sp. = Span in feet.

Table 7-d.

Distance along beam span requiring shear steel (for safe shear at 75 lbs./sq")

(Note:—Figures tabulated give value of "k" in inches)

$\frac{S_p}{V_s}$	10'	11'	12'	13'	14'	15'	16'	17'	18'	19'	20'	21'	22'	23'	24'
250	37.5	41.2	45	48.7	52.5	56.2	60	63.7	67.5	71.2	75	78.8	82.5	86.2	90
185	35.8	40.8	44.8	48	51.7	55.4	59	62.8	66.5	70.2	74	77.8	81.3	85	88.7
160	35.32	40	43.5	47.2	50.8	54.4	58	61.7	65.2	68	72.5	76.2	79.8	83.5	87
155	35.7	39.5	43.5	46.4	50	53.6	57.2	60.8	64.3	68	71.5	75	78.4	82.2	85.8
150	35	38.5	42	45.5	49	52.5	56	59.5	63	66.5	70	73.5	77	80.4	84
175	34.8	37.7	41.2	44.6	48	51.5	54.8	58.2	61.7	65.2	68.6	72	75.3	78	82.4
170	33.5	37	40.3	43.6	47	50.3	53.7	57	60.4	63.8	67.2	70.6	74	77.2	80.7
165	32.7	36	39.3	42.5	45.8	49	52.3	55.6	59	62.2	65.5	68.7	72	75.3	78.6
150	31.5	35.1	38.3	41.5	44.7	47.8	51.1	54.2	57.5	60.7	63.8	67	70.2	73.5	76.7
155	31	34.1	37.2	40.2	43.4	46.5	49.7	52.7	56.8	59	62	65.2	68.2	71.4	74.5
150	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72
145	29	31.6	34.8	37.7	40.8	43.5	46.3	49.4	52.2	55.2	58	61	64.2	67.3	70.7
140	27.9	30.7	33.5	36.3	39.1	41.9	44.7	47.5	50.2	53	56	58.7	61.5	64.2	67
135	26.7	29.4	32	34.7	37.4	40	42.6	45.6	48.1	50.7	53.4	56.1	58.8	61.4	64.1
130	25.4	27.8	30.5	33	35.6	38.1	40.7	43.2	45.7	48.2	50.9	53.4	56	58.5	61
125	24	26.4	28.8	31.2	33.6	36	38.4	40.8	43.2	45.7	48	50.5	52.8	55.2	57.7
120	22.5	24.8	27	29.2	31.5	33.8	36	38.2	40.5	42.7	45	47.2	49.3	51.5	54
115	22.1	22.1	24.1	26.1	28.1	30.2	32.2	34.2	36.2	38.2	40.2	42.2	44.2	46.2	48.2
110	18	20.0	22.5	24.7	26.8	28.9	30.9	32.9	34.9	36.9	38	40	41.8	43.7	45.6
105	17.3	18.9	20.6	22.4	24.1	25.8	27.5	29.2	31	32.7	34.4	36.1	37.9	39.6	41.3
100	15	16.5	18	19.5	21	22.5	24	25.5	27	28.5	30	31.5	33	34.5	36
95	12.6	13.8	15.1	16.4	17.6	18.9	20.4	21.4	22.7	23.9	25.2	26.5	27.7	29	30.2
90	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
85	7	7.7	8.4	9.1	9.8	10.5	11.2	11.9	12.4	13.2	14	14.8	15.6	16.4	17.2
80	5.6	6.1	6.5	6.9	7.3	7.8	8	8.4	8.8	9.2	9.6	9.9	10.2	10.6	10.9
75															



Sp.—Span in feet.

SHEAR

spacings of stirrups are given in Tables 7-e and 7-f. From these tables spacing of stirrups in a particular portion of a beam can be found: (see example).

7.2 EXAMPLE.

Find the pitch of stirrups at the end portion of a 20' span. 20"×10" beam with end shear *S* of 24000 lbs. 2—1" ϕ bars are available for being bent up.

2—1" ϕ @ 45° give 18000 lbs.

Balance to be provided by stirrups=6000 lbs.

$$S/jd = \frac{6000}{20 \times .88} = 340$$

Hence $\frac{1}{4}$ " stirrups should be placed at $4\frac{1}{2}$ " ϕ s. It is necessary to calculate the spacing of stirrups at various points as shown and arrange them properly, in a practical and simple manner.

Explanation of chart No. 7-1.

This chart can be used for any type of shear diagram but it is more useful in case of triangular shear diagram; the use will be understood from example below:—

Example above

Balance *S*=6000 lbs. *jd*=17.6" say 17.5 for chart.

$\frac{1}{4}$ " stirrups @ $4\frac{1}{2}$ " are required according to the chart.

Find stirrups for the whole beam as above when no bars are available for bending up.

S/jd=1365 from chart so *S/bjd*=136.

Shear taken by concrete @ 60 lbs.=10800 lbs. from chart. Stirrups are required from portion A to B of the beam; length AB=66" from Table No. 7-e. This much length is given by 31 divisions in the chart.

So the spacing of $\frac{1}{4}$ " stirrups is—

$4\frac{1}{2}$ " for 31 divisions from support i.e. $\frac{13}{31} \times 66 = 28$ " say			
6"	10	"	—21" "
8"	4	"	— 8" "
9"	4"	"	— 8" "
			65"

Total length to be reinforced for shear checks with Table No. 7-e.

CHAPTER 8

DESIGN OF R.C. COLUMNS

CONTENTS

8.1 General formulæ.

8.2 Increase of stress due to extra binding in old regulations.

8.3 Details of columns New & Old L.C.C., and D.S.I.R. Code.

8.4 Effect of slenderness of columns.

8.5 Effect of helical bindings.

8.6 Charts and tables for design.

Chart No. 8-1. Safe loads on square circular or octagonal columns with different reinforcement (New L.C.C.R.).

Tables of safe loads, reinforcement quantities, etc., for square columns.

8.7 Estimating tables of formwork, etc. for columns.

8.8 Illustrative examples.

8.9 Eccentric loading.

CHAPTER 8

R.C. COLUMNS

8.1 GENERAL FORMULAE.

The general formula for design of columns loaded with axial loads is

$$P = \left\{ \begin{array}{l} \text{the load carried by} \\ \text{a short column} \end{array} \right\} = \text{Concrete stress} \times \text{Concrete area} + \text{Steel stress} \times \text{steel area}$$

(a) *Concrete Area* is assumed as follows:—

Old L.C.C.R. d^2 : Core area (shown hatched in para 8.3 (b) less area of steel. Av.

New L.C.C.R. D^2 : Gross cross sectional area—area of steel—area of champhers.

(b) *Steel area* is the area of longitudinal bars only.

(c) *Concrete stress* & modular ratios. (stress in lbs per sq. inch)

Old L.C.C.R.	600	1 : 2 : 4 mix	m=15
	750	1 : 1 : 2 mix	m=12

New L.C.C.R.	1000	1 : 1 : 2	(A quality)
	780	1 : 1 : 2	(Ordinary)
	880	1 : 1½ : 3	(A quality)
	680	1 : 1½ : 3	(Ordinary)
	760	1 : 2 : 4	(A quality)
	600	1 : 2 : 4	(Ordinary)

m=15

D.S.I.R. Code same as above. Concrete styled high grade in place of A quality.

I.S.I. Code

900 1 : 1 : 2

750 1 : 1½ : 3

600 1 : 2 : 4

In case of old L.C.C.R. concrete stress can be increased to some extent if extra volume of lateral binding is used as given in Statement in para 8.2; in this case

the value of m is to be taken as $\frac{9000}{\text{increased stress}}$

(d) *Steel Stress*

Old L.C.C.R. $m \times \text{concrete stress}$

New L.C.C.R. $m \times \text{concrete stress}$

D.S.I.R. Code 13500 lbs./sq. inch (ordinary steel)

D.S.I.R. Code 15000 lbs./sq. inch (special steel)

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Value of safe loading in different types of columns calculated on above principles are given in Chart No. 8-1 and Table No. 8-a.

I.S.I. Code } 18,000 lbs./sq. inch.
B.S. Code }

R.C.C. COLUMNS (NEW L.C.C. BY-LAWS)

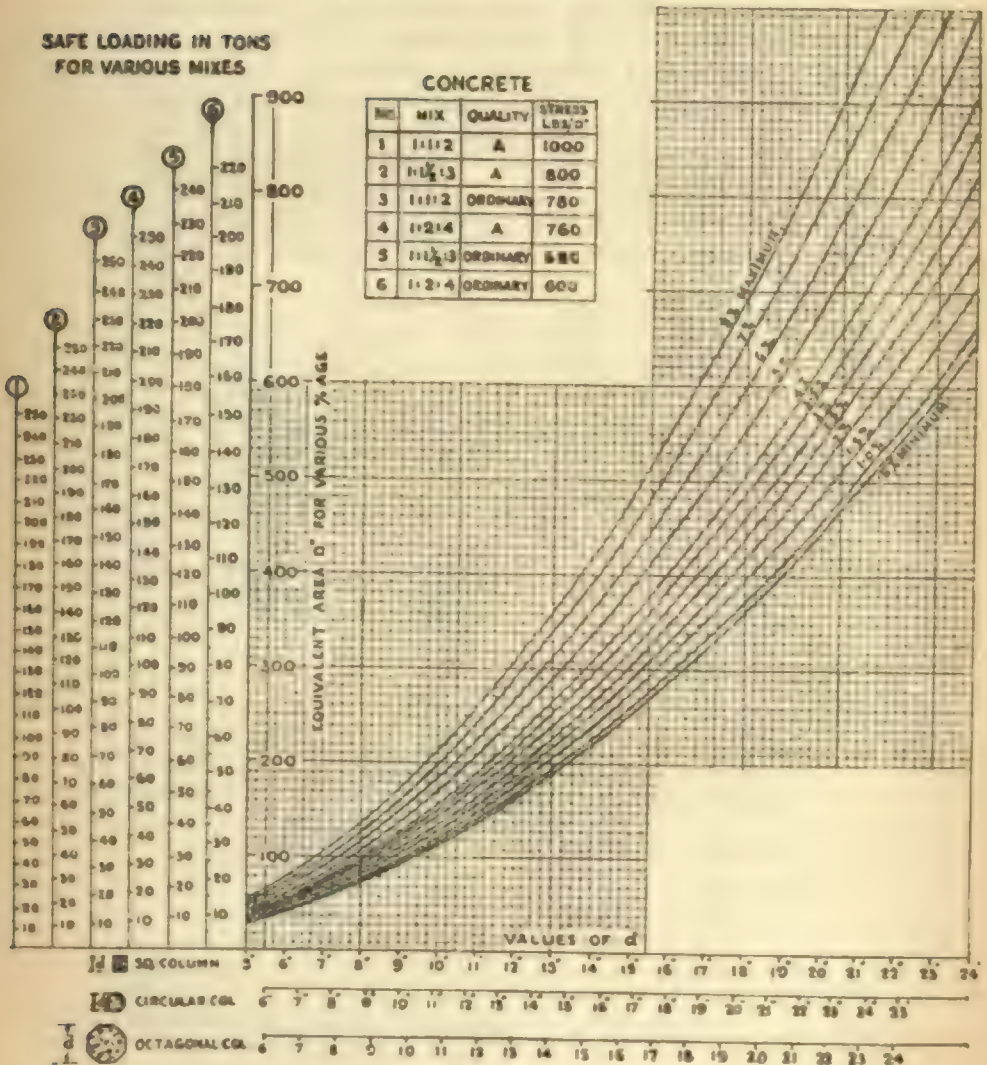


Chart 8-1

DESIGN OF R.C. COLUMNS

8.2 INCREASED COMPRESSIVE STRENGTH.

Cross binding of the longitudinal reinforcement of columns adds to the compressive strength of the concrete to some extent. The following increment in stress permitted by old regulations may be noted.

Volume of binding expressed as percentage of core volume	Pitch of binding	Form of binding		
		Spiral	Circular separate links	Rectilinear separate links
.50	.2d or less	1.16	1.12	1.08
0.75		1.24	1.18	1.12
1.00		1.32	1.24	1.16
1.25			1.30	1.20
1.50				1.24
1.75				1.28
2.00				1.32
0.50	0.3d or less	1.12	1.09	1.06
0.75		1.18	1.14	1.09
1.00		1.24	1.18	1.12
1.25		1.30	1.23	1.15
1.50			1.27	1.18
1.75			1.32	1.21
2.00				1.24
0.50	0.4d or less	1.08	1.06	1.04
0.75		1.12	1.09	1.06
1.00		1.16	1.12	1.08
1.25		1.20	1.15	1.10
1.50		1.24	1.18	1.12
1.75		1.28	1.21	1.14
2.00		1.32	1.24	1.16
0.50	0.5d or less			1.02
0.75				1.03
1.00				1.04
1.25				1.05
1.50				1.06
1.75				1.07
2.00				1.08
Any percentage	0.6d			1.00

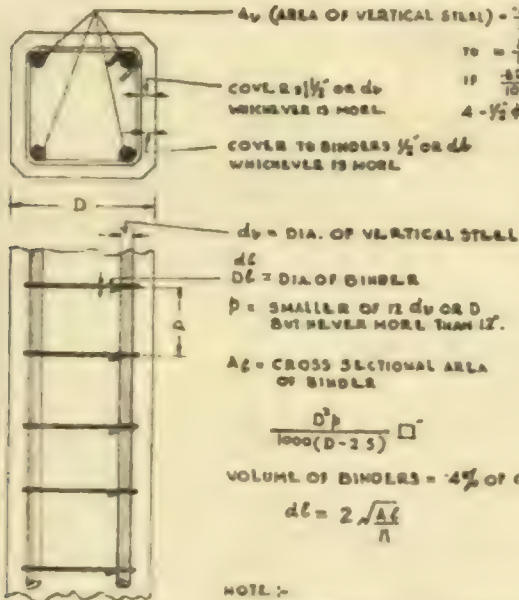
NOTE :—The concrete stress can never be increased to more than $1\frac{1}{2}$ fc viz. 800 lbs/sq. inch.

CONCRETE ENGINEERS' HANDBOOK

8.3 DETAILS OF COLUMNS.

COLUMNS

NEW L.C.C. & D.S.I.R. CODE



$$4v \text{ (AREA OF VERTICAL STEEL)} = \frac{4d_v^2}{100}$$

$$70 = \frac{4d_v^2}{100}$$

$$\text{IF } \frac{4d_v^2}{100} \text{ IS LESS THAN } 785 \text{ CM}^2$$

$$4 - \frac{1}{2}'' \phi \text{ BARS MUST BE PROVIDED}$$

d_v = DIA. OF VERTICAL STEEL
 d_b = DIA. OF BINDER
 p = SMALLER OF $12 d_v$ OR D
 BUT NEVER MORE THAN $12''$.

A_b = CROSS SECTIONAL AREA OF BINDER

$$\frac{D^2 p}{1000(D-2.5)} \square$$

VOLUME OF BINDERS = 4% OF CONCRETE

$$d_b = 2 \sqrt{\frac{A_b l}{\pi}}$$

NOTE :-

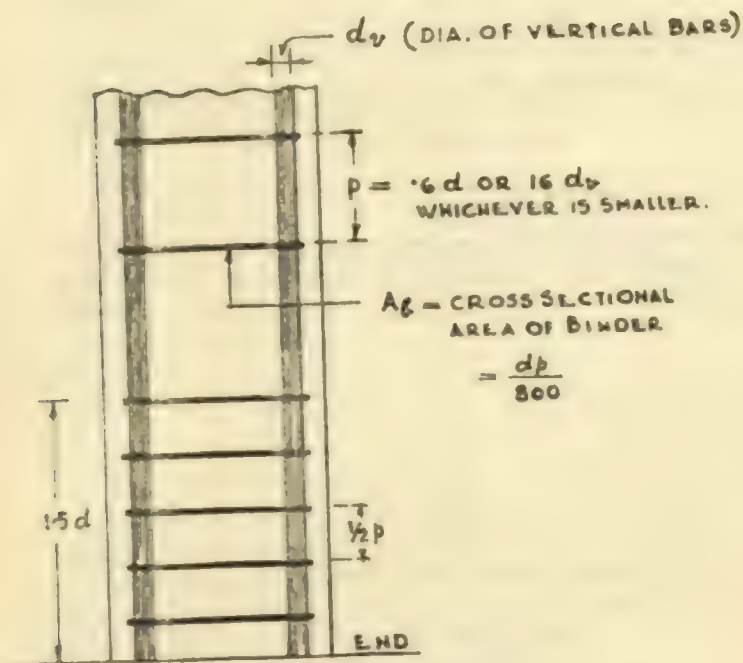
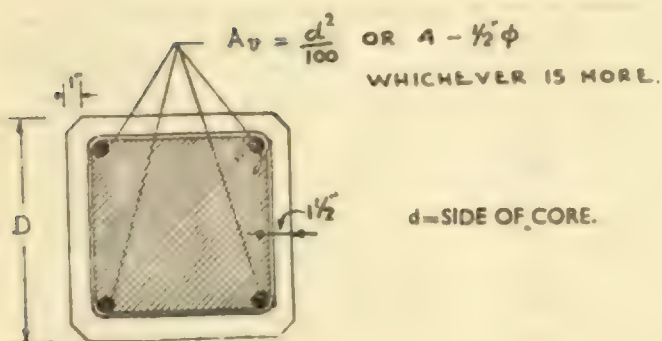
VALUE OF A_b AS CALCULATED FROM FORMULA ABOVE IS APPROXIMATE

Note:

Where it is necessary to splice the longitudinal reinforcement the rods must be lapped in contact with one another, the length of the lap being not less than 24".

DESIGN OF R.C. COLUMNS

OLD L. C. C. R



CONCRETE ENGINEERS' HANDBOOK

8.4 EFFECT OF SLENDERNESS OF COLUMNS ON SAFE LOAD P .

(a) *New L.C.C. Regulations.*

Any Cols. v/g	Square Cols. v/d	Safe load allowed.
50	15	$1.0 \times P$
60	18	$0.9 \times P$
70	21	$0.8 \times P$
80	24	$0.7 \times P$
90	27	$0.6 \times P$
100	30	$0.5 \times P$
110	33	$0.4 \times P$
120	36	$0.3 \times P$
121	39	Nil

Notes: d and g to be taken on gross section basis, except in case of helically wound columns where g to be taken on core basis.

(b) *Old L.C.C. Regulations.*

Square Cols. v/d	Round Cols. v/d	Any Col. v/g	Safe load allowed
15	12	45	$1.0 \times P$
18	15	54	$0.8 \times P$
21	18	63	$0.6 \times P$
24	21	72	$0.4 \times P$
27	24	82	$0.2 \times P$
30	27	90	Nil

Notes: v —virtual length. See table on next page.
 d —effective diameter of column measured across core in direction of lateral supports which determine its length.
 g —least equivalent radius of gyration ascertained on the core area.

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Rectangular & round Cols. v/d	Any Col. v/g	Safe load allowed
15	50	$1.0 \times P$
18	60	$0.9 \times P$
21	70	$0.8 \times P$
24	80	$0.7 \times P$
27	90	$0.6 \times P$
30	100	$0.5 \times P$
33	110	$0.4 \times P$
36	120	$0.3 \times P$
39	130	$0.2 \times P$
42	140	$0.1 \times P$
45	150	Nil

Relation between virtual length 'v' & actual length 'l'.

Old L.C.C.R.

- i Both ends of column fixed in position & direction:
 $v=l$
- ii One end of column fixed in position & direction
and one end fixed in position only (hinged)
 $v=1.4l$
- iii Both ends fixed in position only and not in direc-
tion:
 $v=2l$
- iv One end fixed in position and direction and one end
free e.g. a mast, flagstaff, etc. $v=4l$

Note: l is taken as clear distance between lateral supports.

New L.C.C.R. & D.S.I.R. Code of Practice:

	Cols. of 1 storey	Cols of 2 storeys & above
i Both ends fixed in position & direction $v = 0.75 l$		$0.75 l$
ii Both ends fixed in position & not in direction	l	$0.75 \text{ to } 1 l$
iii One end fixed in position & direction and One end imperfectly fixed in both position and direction	$1 \text{ to } 2 l$	$1 \text{ to } 2 l$

Note: length 'l' is measured as follows.

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- l : to be measured between upper surfaces of two floors affording lateral support or to be the clear distance between supports plus the lateral dimension of the column.

New L.C.C.R.

- l : to be the actual length with single storey columns and to be the distance from floor level to floor level with other columns.

8.5 HELICAL BINDING OF COLUMNS.

Old L.C.C.R.

Safe stress in concrete can be increased to 1.33fc as already stated.

New L.C.C.R. and D.S.I.R. Code

The safe stress on concrete cannot be increased as above but additional load of $2tbAb$ (i.e. 27000 Ab lbs. tb being 13500 lbs for both codes) can be allowed on the column. However the safe load on the column is to be calculated on core area basis and not on gross area basis.

Thus $P = P_c + P_T + P_B$ where

P_c = load carried by concrete in core

P_T = " " vertical steel

P_B = additional load due to helical binding

$$= 2tbAb - 27000 Ab$$

Ab = volume of helical binding per unit length of column.

The pitch of helicals not to be more than 3" or $1/6$ of core diameter whichever is less. For practical reasons not more than $\frac{1}{2}$ " ϕ bars and not less than $3/16$ " dia. should be used for forming the helical binding. The values of P_B for different column size and arrangement of helical windings can be found from the Chart 8-2.

BATCH OF BINDING
 3" 2½" 2" 1½" 1"

R.C.C. COLUMNS

NEW L.C.C. BY-LAWS.

EFFECT OF HELICAL BINDING.

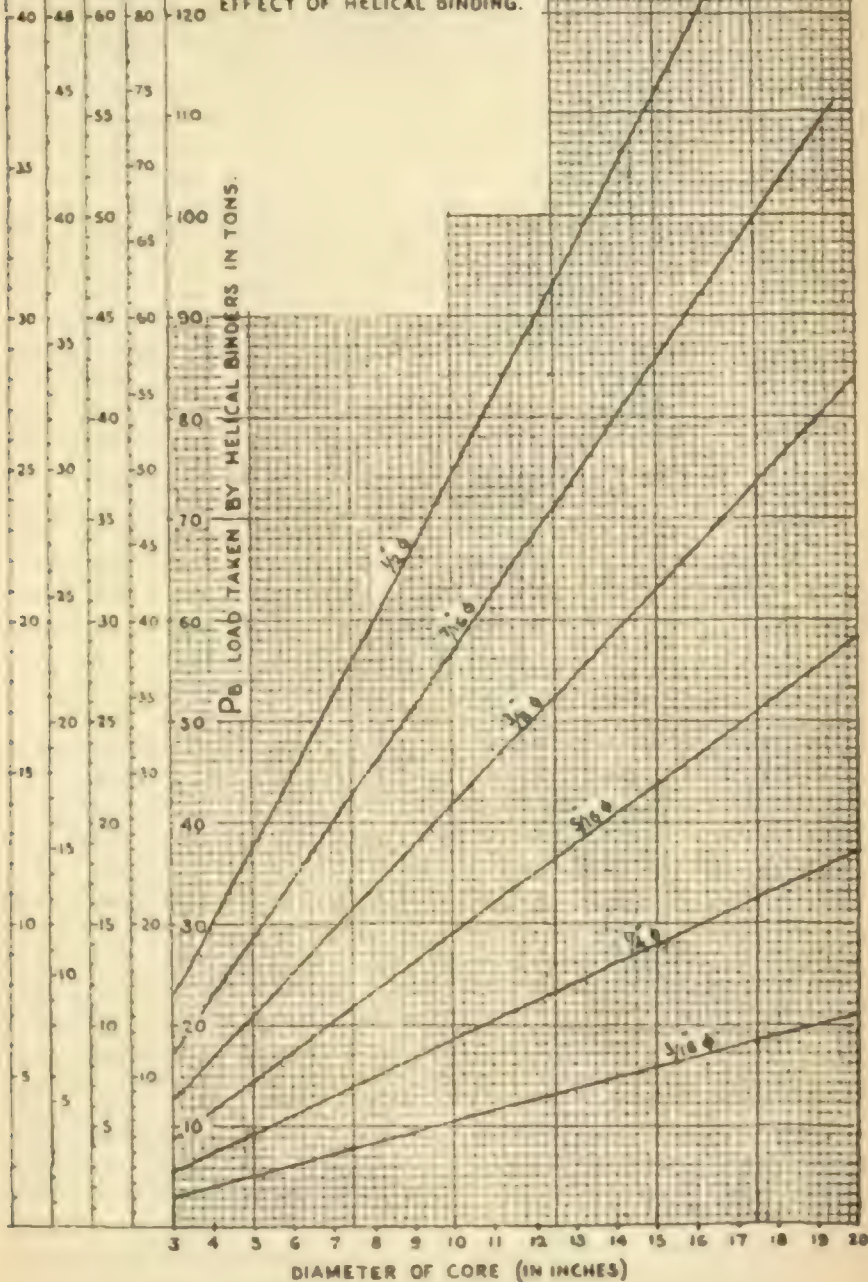


Chart 8-2

8.6 CHARTS AND TABLES FOR DESIGN.

Table 8-2

SQUARE COLUMNS (New L.C.C.R.)

Ref	D Inches	d Inches	Av.		Strps.		Safe Load Tons	Concrete C. Ft. in 10' Ht.	Steel Lbs. 10' Ht.	
			Nos.	Dia. Inches	Pitch Inches	Dia. Inches			Main	Strps.
C1	6"	3	4	$\frac{1}{2}$	4	$\frac{1}{2}$	13	2-36	28-00	9-5
C2a	8"	5	4	$\frac{1}{2}$	6	$\frac{1}{2}$	20	4-35	38-00	10-70
C2b	8	5	4	$\frac{1}{2}$	6	$\frac{1}{2}$	21-5	4-35	41-00	10-70
C3a	9	6	4	$\frac{1}{2}$	6	$\frac{3}{4}$	24-7	5-48	28-00	22-30
C3b	9	6	4	$\frac{1}{2}$	7	$\frac{3}{4}$	26-0	5-48	43-70	19-11
C3c	9	6	4	$\frac{1}{2}$	7	$\frac{3}{4}$	29-4	5-48	53-00	19-11
C4a	10	7	4	$\frac{1}{2}$	8	$\frac{1}{2}$	29-8	6-75	28-00	24-00
C4b	10	7	4	$\frac{1}{2}$	8	$\frac{1}{2}$	31-4	6-75	42-00	24-00
C4c	10	7	4	$\frac{1}{2}$	8	$\frac{1}{2}$	33-8	6-75	53-00	24-00
C4d	10	7	4	$\frac{1}{2}$	8	$\frac{1}{2}$	34-5	6-75	55-00	24-00
C4e	10	7	4	1	8	$\frac{1}{2}$	35-0	6-75	114-01	24-00
C5a	12	9	4	$\frac{1}{2}$	8	$\frac{1}{2}$	43-2	9-86	43-00	30-17
C5b	12	9	4	$\frac{1}{2}$	8	$\frac{1}{2}$	46-8	9-86	63-00	30-17
C5c	12	9	4	$\frac{1}{2}$	8	$\frac{1}{2}$	47-6	9-86	85-00	30-17
C5d	12	9	4	1	8	$\frac{1}{2}$	50-4	9-86	114-01	30-17
C5e	12	9	8	$\frac{1}{2}$	8	$\frac{1}{2}$	56-4	9-86	171-00	30-17
C6a	14	11	4	$\frac{1}{2}$	9	$\frac{1}{2}$	59-2	12-55	53-00	33-78
C6b	14	11	4	$\frac{1}{2}$	10	$\frac{1}{2}$	61-5	13-55	53-00	33-19
C6c	14	11	4	1	10	$\frac{1}{2}$	64-8	13-55	114-01	33-19
C7a	15	12	4	$\frac{1}{2}$	9	$\frac{1}{2}$	69-8	15-50	53-00	45-08
C7b	15	12	4	1	9	$\frac{1}{2}$	72-1	15-50	114-01	45-08
C7c	15	12	8	$1\frac{1}{2}$	9	$\frac{1}{2}$	75-3	15-50	148-72	45-08
C8a	16	13	4	$\frac{1}{2}$	8	$\frac{1}{2}$	77-7	17-7	53-00	48-26
C8b	16	13	4	1	8	$\frac{1}{2}$	80-0	17-7	114-01	48-26
C8c	16	13	4	$1\frac{1}{2}$	8	$\frac{1}{2}$	83-7	17-7	148-72	48-26
C8d	16	13	8	1"	9	$\frac{1}{2}$	93-1	17-7	229-00	48-26
C9a	18	15	4	1	8	$\frac{1}{2}$	96-8	22-4	114-01	62-19
C9b	18	15	4	$1\frac{1}{2}$	8	$\frac{1}{2}$	103-0	22-4	148-72	62-19
C10a	20	17	4	$1\frac{1}{2}$	8	$\frac{1}{2}$	122-0	27-00	148-72	69-33
C10b	20	17	8	1	8	$\frac{1}{2}$	122-12	27-00	229-00	69-33
C10c	20	17	8	$1\frac{1}{2}$	8	$\frac{1}{2}$	139-0	27-00	297-44	69-33
C11a	21	18	8	$1\frac{1}{2}$	8	$\frac{1}{2}$	150-0	30-4	297-44	69-33
C11b	21	18	8	$1\frac{1}{2}$	8	$\frac{1}{2}$	154-0	30-4	307-00	69-33

Table 8-b
SQUARE COLUMNS (Old L.C.C.R.)

Ref. No	D Inches	d Inches	Av.		Strips.		Safe Load Tons	Concrete c. ft. in 10' Ht	Steel Lbs. 10' Ht	
			Nos.	Dia. Inches	Pitch Inches	Dia. Inches			Main	Strips
C1	8	5	4	1/2	3	1/10	10	4-35	28	9-6
C2	9	6	4	1/2	3 1/2	1/10	10	5-48	28	9-31
C3a	10	7	4	1/2	4 1/4	1/8	16	6-75	28	15-3
C3b	10	7	4	1/2	4 1/4	1/8	16	6-75	43-7	15-3
C4a	12	9	4	1/2	4 1/2	1/8	26	8-88	43-7	18-3
C4b	12	9	4	1/2	4 1/2	1/8	26	8-88	53-0	18-6
C4c	12	9	4	1/2	4 1/2	1/8	30	9-88	65-7	18-6
C5a	14	11	4	1/2	5 1/2	1/10	37	13-55	48-7	27-0
C5b	14	11	4	1/2	5 1/2	1/10	39	13-55	63-0	27-0
C5c	14	11	4	1/2	5 1/2	1/10	42	13-55	85-7	27-0
C5d	14	11	4	1	5 1/2	1/10	44	13-55	114-8	27-0
C6a	15	12	4	1/2	7 1/4	1/8	45	15-5	68	32-6
C6b	15	12	4	1/2	7 1/4	1/8	48	15-5	85-7	32-6
C6c	15	12	4	1	7 1/4	1/8	51	15-5	114-8	32-6
C7a	16	13	4	1/2	7 1/2	1/8	52	17-7	43	38-6
C7b	16	13	4	1/2	7 1/2	1/8	54	17-7	65-7	38-6
C7c	16	13	4	1	7 1/2	1/8	57	17-7	114-8	38-6
C7d	16	13	4	1 1/2	7 1/2	1/8	60	17-7	148-7	38-6
C8a	18	15	4	1/2	9	1/8	88	22-4	85-7	54-4
C8b	18	15	4	1	9	1/8	72	22-4	114-8	54-4
C8c	18	15	8	1 1/2	9	1/8	75	22-4	148-7	54-4
C8d	18	15	8	1 1/2	9	1/8	78	22-4	171-4	54-4
C9a	20	17	4	1	9	1/8	89	27-6	114-8	60-7
C9b	20	17	4	1 1/2	9	1/8	91	27-6	148-7	60-7
C9c	20	18	8	1 1/2	9	1/8	95	27-6	171-4	60-7
C9d	20	17	8	1	9	1/8	100	27-6	229-6	60-7
C10a	22	19	8	1 1/2	8	1/8	112	33-4	148-7	76-5
C10b	22	19	8	1 1/2	8	1/8	115	33-4	171-4	76-5
C10c	22	19	8	1	8	1/8	119	33-4	229-6	91-5
C10d	22	19	8	1 1/2	8	1/8	120	33-4	297-4	91-5
C11a	24	21	4	1 1/2	10	1/8	137	39-9	183-5	105-9
C11b	24	21	8	1 1/2	10	1/8	136	39-9	171-4	105-9
C11c	24	21	8	1	10	1/8	142	39-9	229-6	105-9
C11d	24	21	8	1 1/2	10	1/8	145	39-9	297-4	105-9

SQUARE COLUMNS I.S.I. CODE

Table 8-c.

Size (in)	Longitudinal Steel		Load carried by longitudinal bars at 16,000 lbs. per sq. in.	Load carried by the Column Lbs.			
	No.	Bars Dia.		Area (Sq. in.)	Lbs.	1:2:4 600 p.s.i.	1:1½:3 750 p.s.i.	1:1:2 900 p.s.i.
8	4	¾	9.79	14,100	52,100	61,500	70,900
	4	1	3.14	56,600	93,100	107,200	111,300
	4	1½	4.91	58,400	123,900	132,700	141,000
9	4	¾	9.79	14,100	52,100	74,300	86,800
	4	1	3.14	56,600	103,300	116,000	126,800
	8	1	6.28	113,100	158,000	169,100	180,500
10	4	¾	1.23	22,100	81,300	96,200	110,900
	4	1½	3.98	71,600	129,200	148,600	156,000
	8	1½	7.95	143,100	199,400	212,100	223,800
11	4	¾	1.23	22,100	93,900	111,800	123,800
	4	1½	4.91	58,400	158,100	175,500	191,900
	4	2	6.82	173,200	240,000	254,700	274,200
12	4	¾	1.23	22,100	107,700	129,100	150,500
	4	1½	5.94	106,900	189,500	210,700	231,300
	8	1½	9.82	176,700	257,300	277,500	297,700
13	4	¾	1.77	31,500	132,800	157,300	182,400
	8	1	6.28	113,100	210,700	235,100	259,500
	10	1½	12.27	220,900	314,900	336,400	361,900
14	4	¾	1.77	31,500	148,600	177,600	206,500
	8	1	6.28	113,100	227,100	255,300	284,100
	8	1½	14.14	254,500	364,500	391,000	418,800
15	6	¾	1.84	33,100	167,100	200,600	234,100
	8	1½	9.82	176,700	305,700	338,200	370,200
	12	1½	17.62	329,700	445,200	476,200	507,200
16	4	¾	2.41	43,300	195,500	233,400	271,300
	8	1½	11.88	213,800	360,300	396,800	433,800
	8	2	19.24	346,400	488,500	524,400	569,400
17	4	¾	2.41	43,300	216,400	259,300	301,300
	8	1½	11.88	213,800	380,000	421,800	463,800
	12	1½	21.21	381,700	542,700	582,700	622,700

Table 8-c (contd.).

Size (in.)	Longitudinal Steel			Load carried by longitudinal bars at 18,000 lbs. per sq. in.	Load carried by the Column Lbs.		
	Bars No.	Dia.	Area (Sq. in.)		1:2:4 600 p.s.i.	1:1½:8 750 p.s.i.	1:1:2 900 p.s.i.
18	4	1	3-14	56,600	249,600	207,900	345,600
	8	1½	14-14	251,500	440,500	487,000	533,500
	8	2	25-13	652,600	631,900	676,900	721,600
19	4	1	3-14	56,600	271,600	225,100	378,600
	12	1½	14-70	265,100	473,100	525,100	577,100
	12	1½	25-46	519,500	719,000	769,500	818,500
20	8	1½	8-53	63,600	301,600	361,100	421,800
	12	1½	17-82	320,700	519,700	607,200	684,700
	10	2	31-42	565,500	786,000	841,500	897,000
21	8	1½	8-53	63,600	320,600	391,600	457,600
	8	1½	19-24	346,400	599,400	662,000	728,400
	10	2	31-42	565,500	811,500	872,500	934,500
22	8	1½	4-81	86,600	374,800	445,600	516,600
	12	1½	21-21	381,700	659,700	727,700	796,700
	12	2	37-70	678,000	946,600	1,013,600	1,080,600
24	8	1½	4-81	86,600	629,600	514,600	600,600
	12	1½	29-66	519,500	847,900	929,500	1,012,000
	18	1½	43-30	779,300	1,099,300	1,179,300	1,259,300
26	8	1	6-94	113,100	515,100	615,100	716,100
	12	1½	29-66	519,500	907,500	1,004,500	1,102,000
	16	2	50-27	804,600	1,280,600	1,374,600	1,468,600
28	4	1	6-94	113,110	679,100	696,100	813,100
	12	2	37-70	678,600	1,126,600	1,238,600	1,349,600
	20	2	62-63	1,131,000	1,584,000	1,672,000	1,761,000
30	12	1½	7-92	129,900	664,000	796,000	933,000
	16	1½	34-48	692,700	1,209,700	1,337,700	1,467,700
	20	2	66-12	1,244,000	1,743,000	1,867,000	1,992,000
32	12	1	9-43	169,600	778,600	930,600	1,082,600
	16	2	50-27	804,800	1,439,800	1,634,800	1,780,800
	24	2	75-40	1,357,000	1,927,000	2,099,000	2,212,000
34	8	1½	9-82	176,700	863,700	1,036,700	1,208,700
	16	2	56-27	904,800	1,547,800	1,733,800	1,899,800
	20	2	87-26	1,583,000	2,223,000	2,343,000	2,543,000
36	8	1½	11-46	213,800	983,800	1,175,800	1,373,800
	32	1½	54-23	1,018,000	1,792,000	1,947,000	2,134,000
	28	2	87-06	1,563,000	2,307,000	2,488,000	2,671,000

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8.7 ESTIMATING TABLES OF FORM WORK, ETC. FOR COLUMNS.

Sectional areas and perimeters of columns
Per foot height

Dia. or Side	Area	Perimeter	Area	Perimeter	Area	Perimeter	Area	Perimeter	
8"	35	2.09	37	2.21	39	2.31	41	2.47	
10"	55	2.62	58	2.75	60	2.88	69	3.33	
12"	79	3.14	83	3.32	87	3.97	1.00	4.00	
14"	1.07	3.67	1.13	3.86	1.18	4.03	1.37	4.67	
16"	1.40	4.19	1.47	4.42	1.54	4.62	1.74	5.33	
18"	1.77	4.72	1.87	4.96	1.95	5.10	2.25	6.00	
20"	2.16	5.24	2.30	5.50	2.41	5.78	2.78	6.67	
22"	2.63	5.76	2.78	6.06	2.90	6.35	3.35	7.33	
24"	3.14	6.28	3.31	6.62	3.46	6.94	4.00	8.00	
26"	3.69	6.81	3.89	7.17	4.06	7.50	4.71	8.67	
28"	4.27	7.36	4.51	7.80	4.72	8.08	5.43	9.33	
30"	4.91	7.90	5.18	8.25	5.41	8.60	6.25	10.00	
32"	5.58	8.43	5.89	8.80	6.15	9.22	7.13	10.67	
34"	6.31	9.00	6.63	9.38	6.94	9.78	8.08	11.33	
36"	7.06	9.43	7.45	9.92	7.78	10.40	9.00	12.00	
SHAPE	ROUND		OCTAGONAL		HEXAGONAL		SQUARE		

NOTE
Cross sectional areas
are in sq. ft. and
perimeters in linear
feet.

SECTIONAL AREAS OF RECTANGULAR COLUMNS in sq. feet.

SIDES	10"	12"	14"	16"	18"	20"	22"	24"	26"	28"	30"	32"	34"	36"
8"	55	67	78	89	1.00	1.11	1.22	1.34	1.45	1.56	1.67	1.78	1.89	2.01
10"	69	83	97	1.11	1.25	1.39	1.53	1.67	1.80	1.94	2.08	2.22	2.35	2.49
12"	83	1.00	1.17	1.33	1.50	1.67	1.83	2.00	2.17	2.33	2.50	2.67	2.83	3.00
14"	97	1.17	1.37	1.56	1.75	1.93	2.14	2.34	2.53	2.72	2.92	3.12	3.30	3.51
16"	1.11	1.33	1.56	1.78	2.00	2.23	2.45	2.66	2.90	3.11	3.31	3.56	3.78	4.00
18"	1.25	1.50	1.76	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50
20"	1.39	1.67	1.95	2.23	2.50	2.78	3.05	3.33	3.62	3.89	4.17	4.48	4.72	5.01
22"	1.53	1.83	2.14	2.44	2.75	3.05	3.35	3.66	3.97	4.27	4.58	4.89	5.18	5.49
24"	1.67	2.00	2.34	2.66	3.00	3.33	3.66	4.00	4.34	4.68	5.00	5.33	5.66	6.00

DESIGN OF R.C. COLUMNS

8.8 ILLUSTRATIVE EXAMPLES.

1. Find suitable reinforcement for a column 16" x 16" overall size and supporting a load of 80 tons and to be designed according to stresses for 1 : 2 : 4 ordinary grade concrete specified by new L.C.C.R.

From chart put 1.22% vertical steel i.e. $\frac{256}{100} 1.22 = 3.14 \square''$

i.e. 4 - 1" ϕ bars.

2. Find safe load on an octagonal column of 12" across flats with a reinforcement of 8-7 8" ϕ bars and 5/16" helical windings at 1" pitch.

Diameter of core of column

$$= 12'' - (1\frac{1}{2}'' + 1\frac{1}{2}'') + \left(\frac{5''}{16} + \frac{5''}{16} \right) = 9\frac{1}{2}''$$

$$\therefore \text{Area of core} = \pi (9\frac{1}{2})^2 \times \frac{1}{4} = 72.76 \square''$$

$$\therefore \text{Percentage of steel} = \frac{4.81 \times 100}{72.76} = 6.6$$

$$\therefore \text{load carried from chart 8-1.} = 38 \text{ tons}$$

$$\begin{array}{l} \text{load carried by helical winding} \\ \text{from Chart 8-2.} \end{array} = 28 \text{ tons}$$

$$\therefore \text{Total load} = 66 \text{ tons}$$

3. Find safe load on a rectangular column 10" x 24" reinforced with eight 1" ϕ bars made from 1 : 1 : 2 mix ordinary quality.

$$\text{Percentage of steel} = \frac{4.81 \times 100}{24 \times 10} = 2$$

$$\text{Side of corresponding square column} = \sqrt{240} = 15.5$$

Safe load from chart by referring to vertical scale No. 3 is 106 tons.

8.9 COLUMNS WITH ECCENTRIC LOAD OR SUBJECTED TO B.M.

Sometimes columns of a building are not loaded axially but the resultant load is eccentric. Especially in case of external columns of a building, a portion of the bending moment from the end of the beams is transferred to the columns and it is necessary to design the column to stand both direct load and B.M.

Eccentrically loaded columns fall under two cases:

- (1) Columns where the whole section is under compression.
- (2) Columns where only part of the section is under compression whereas the other portion is under tension.

Case (1) In this case the value of e/d is less than

$$\frac{1 + .27p}{6(1 + .14p)} \text{ Thus in the case of columns without steel}$$

this value is $1/6$ (i.e. the line of load falls within middle third of the section). The stress f_c in concrete is given by the formula

$$f_c = \frac{P}{bd} \left[\frac{1}{1 + .14p} + \frac{e}{d} \times \frac{1}{(.167 + .0448p)} \right]$$

$$= \frac{P}{bd} \frac{1}{K}$$

The value of K can be found from the chart 8.3 for various values of p upto 5% and $m = 15$, $\frac{d}{10}$ being the distance of steel rods from the face of the column.

Case (2) In this case it is necessary to first find out the position of the neutral axis by the formula.

$$n_o^3 + 3 \left(\frac{e}{d} - \frac{1}{2} \right) n_o^2 + 6mp \frac{e}{d} n_o - 3mp \left(\frac{2r^2}{d^2} + \frac{e}{d} \right) = 0.$$

DESIGN OF COLUMNS WITH ECCENTRIC LOADS (WHOLE SECTION IN COMPRESSION)

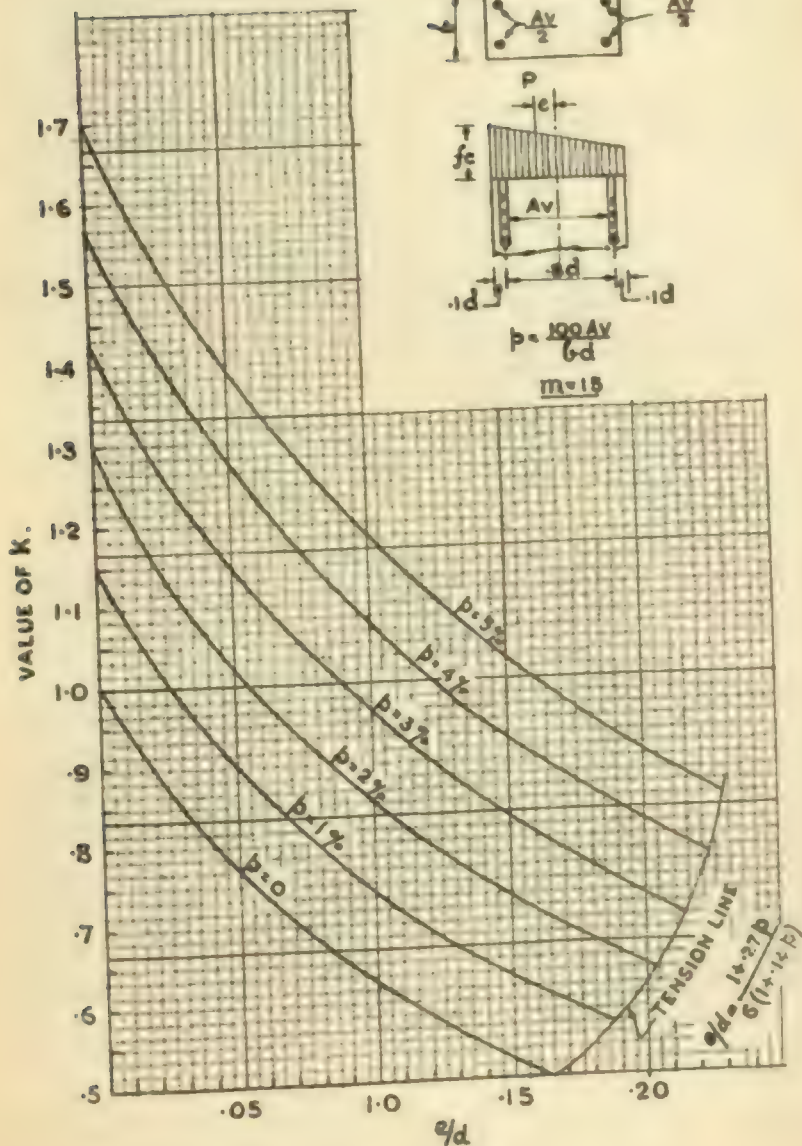
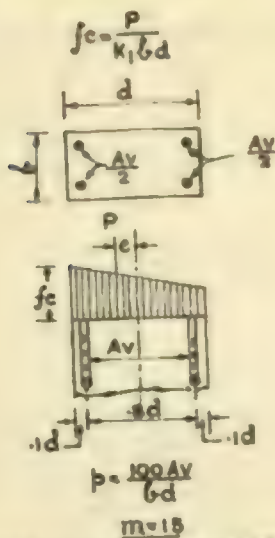


Chart 8-3

DESIGN OF COLUMNS WITH ECCENTRIC LOADS
LOCATION OF NEUTRAL AXIS.

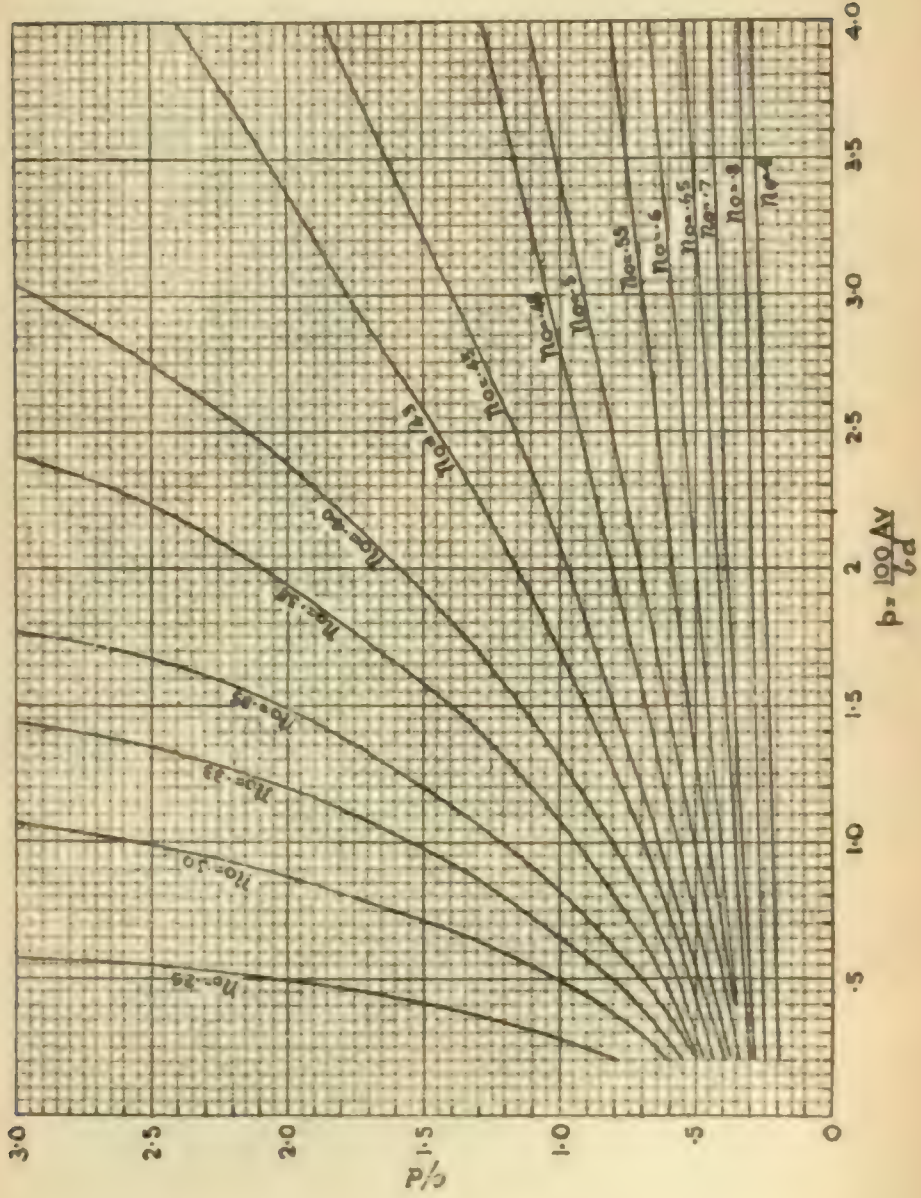


Chart 8-4

DESIGN OF COLUMNS WITH ECCENTRIC LOADS (SECTION PARTLY IN COMPRESSION)

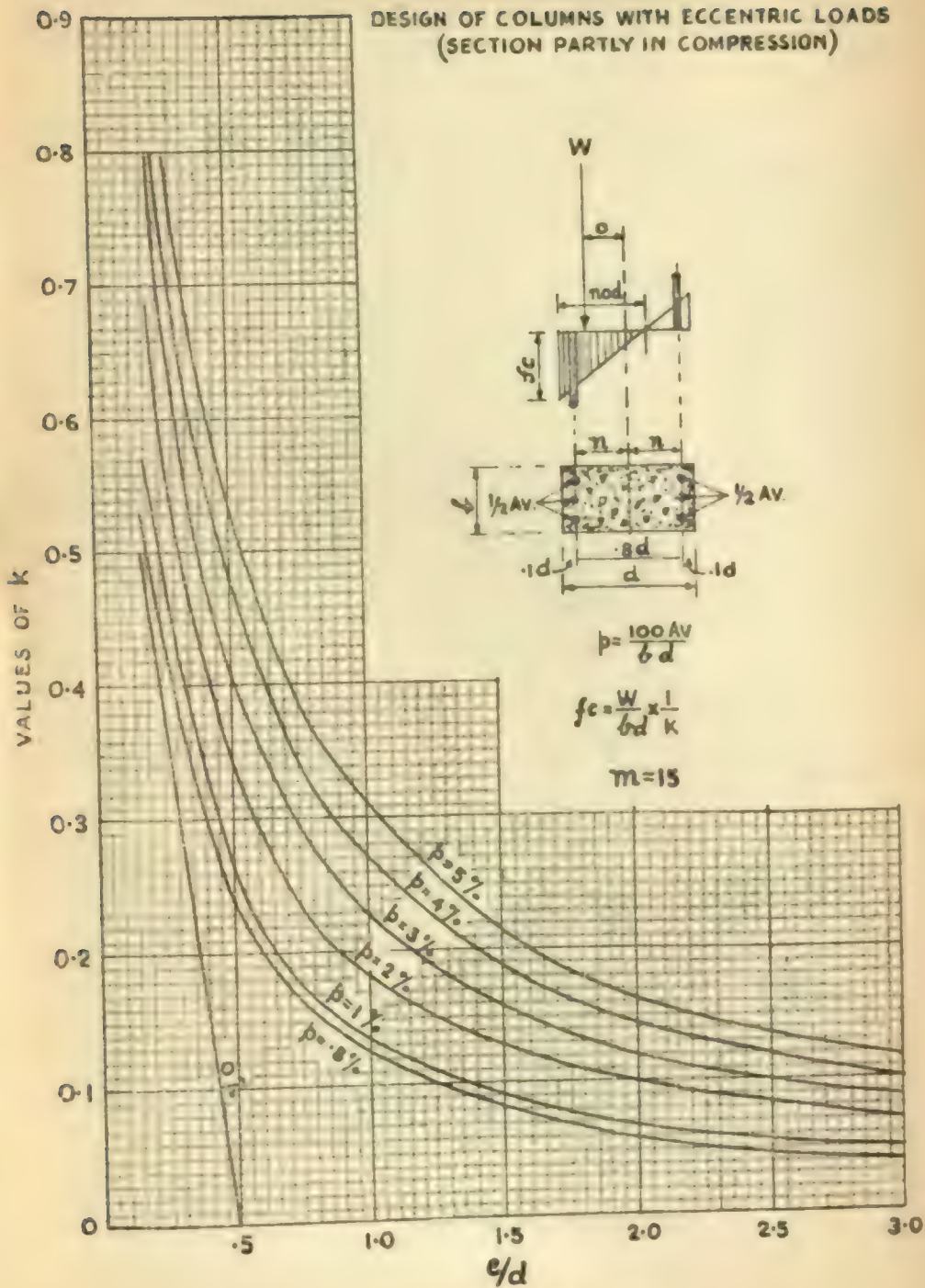


Chart 8-5

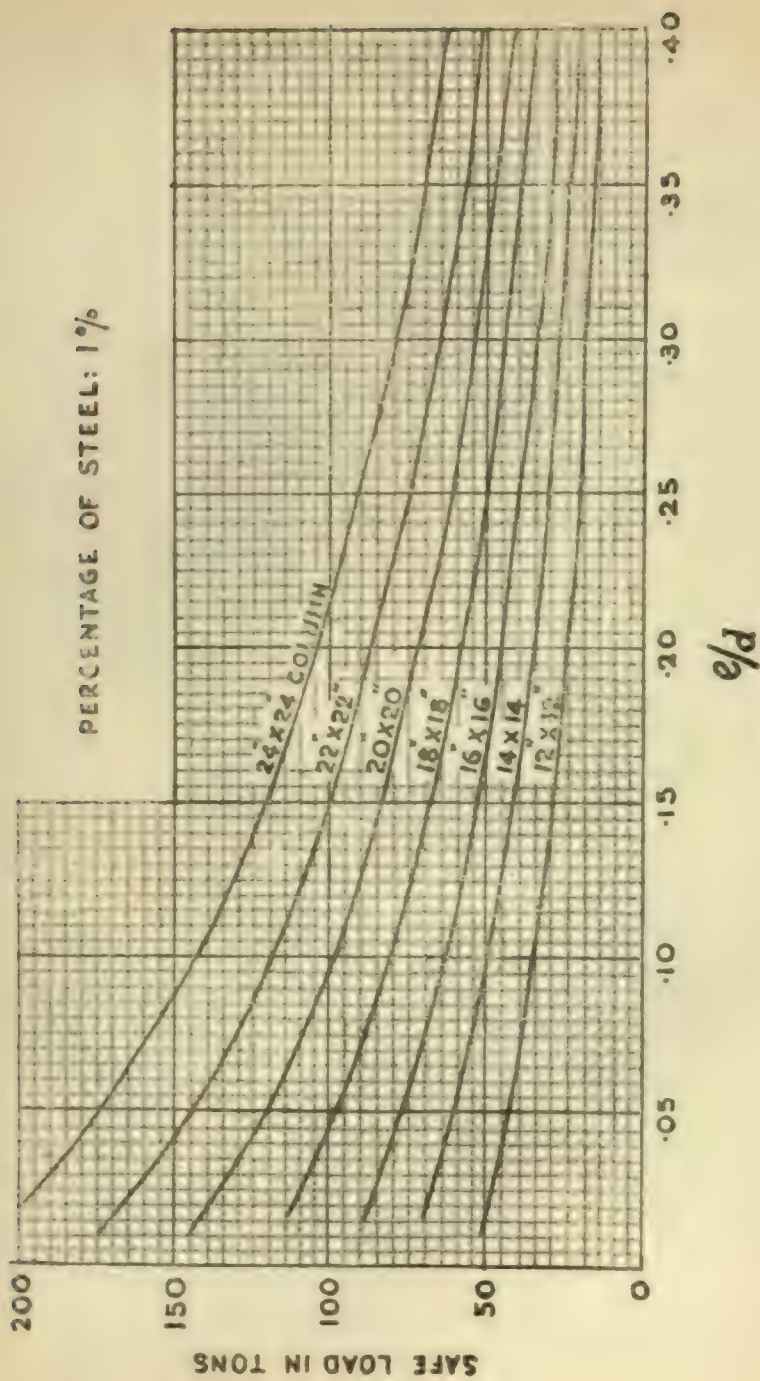


Chart 8-6 (a)

DESIGN OF R.C. COLUMNS

Chart 8-6 (b)

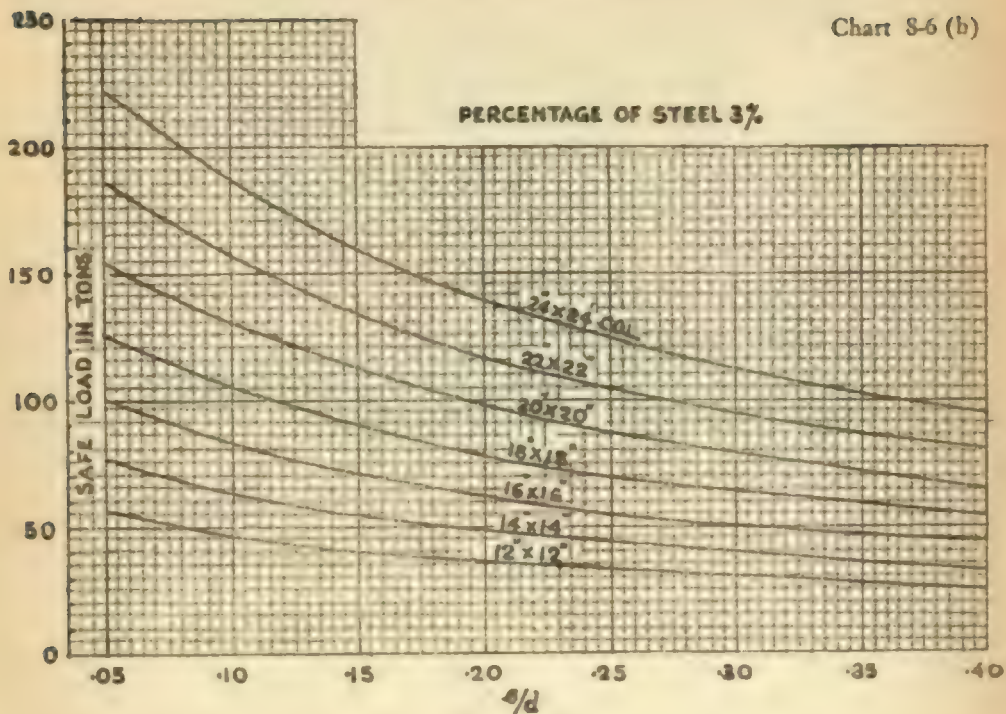
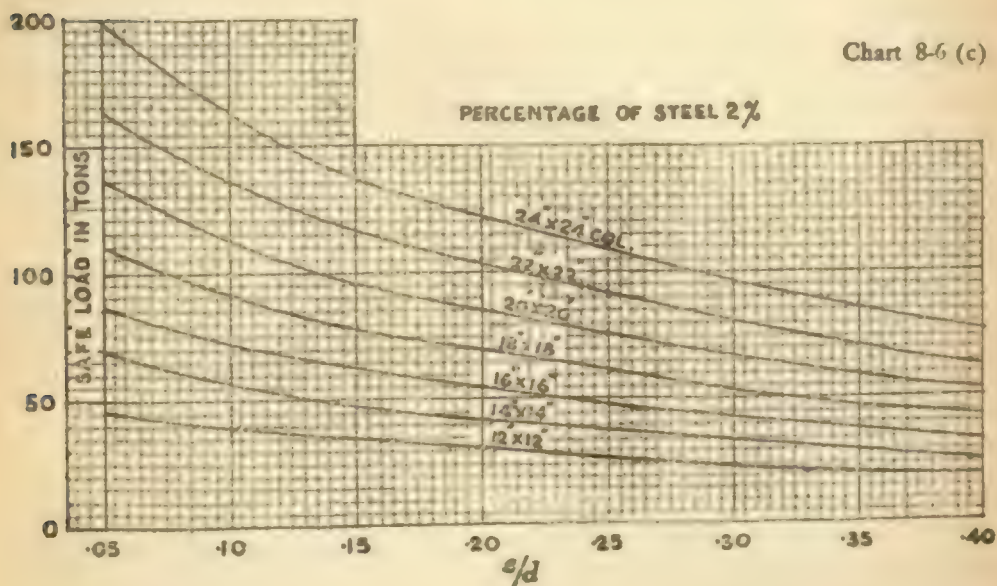


Chart 8-6 (c)



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This being an equation of 3rd degree is difficult to solve. For solution the chart No. 8-4 should be used. After finding the neutral axis, the compressive stresses in concrete and tensile stress in steel are given by:

$$f_c = \frac{W}{bd} \times \frac{2n_o}{n_o^2 + 2mpn_o - mp} = \frac{P}{bd} \times \frac{1}{K} \dots\dots\dots(a)$$

$$f_t = mfc \left(\frac{.9}{n_o} - 1 \right) \dots\dots\dots(b)$$

the values of K can be found from chart No. 8-5.

Charts 8-6, a, b and c give safe loads on eccentrically loaded columns of different sizes and reinforcement.

CHAPTER 9
COLUMN FOOTINGS

CONTENTS

- 9.1. General.
 - 9.2 Illustrative Example.
 - 9.3 Design Tables.
-

CHAPTER 9

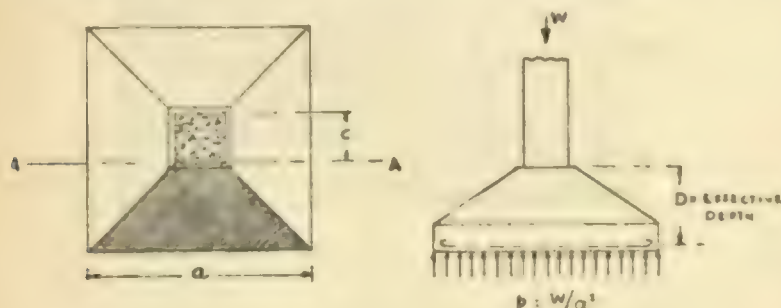
COLUMN FOOTINGS

9.1 GENERAL

Footings for a column must be safe against:

- (a) Punching shear.
- (b) Bending moment and shear due to soil pressure.

In addition, it must be adequately thick to allow proper embedment of the column reinforcement for complete transfer of the column load to the footing. The minimum thickness for the above condition should be 30 times the diameter of the column steel.



(a) *Punching shear:*

The perimeter of the column \times depth of footing \times safe punching shear = total punching force.

$$\text{i.e. } 4c \times D \times Sp = p(a^2 - c^2)$$

Safe punching shear is taken as twice the safe ordinary shear
i.e. 120 lbs./sq. inch and 150 lbs./sq. inch for Old and New L.C.C.R. respectively.

(b) *Bending moment.*

$$M = \frac{Wa}{24} (2 + R) (1 - R)^2 \text{ inch lbs.} = \frac{Wak}{24} \text{ inch lbs.}$$

where W —column load in lbs.

a —length of the side of the footing in inches.

$$R = \frac{\text{Size of column}}{\text{Size of base}}$$

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This moment is at critical section AA. and is caused by soil pressure acting upwards on the hatched portion of the footing.

The values of constant k are given in chart 9-1 for various values of ratio R .

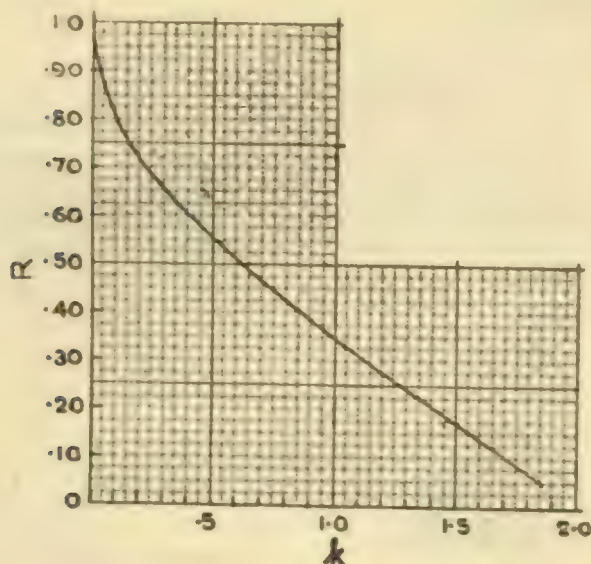


Chart 9-1.

The effective breadth of the footing is taken as

$$c + 2D + \frac{1}{2}(a - c - 2D)$$

9.2 ILLUSTRATIVE EXAMPLE.

Design r.e. footing for a column for the following conditions:—

W—load on column—126 tons

c—size of column—21 inches

P—safe pressure on soil—3 tons/s.ft.—43.7 lbs./sq. in

Sp—safe punching stress—150 lbs./sq. in.

Diameter of column reinforcement—1".

COLUMN FOOTINGS

(a) Size of footing:

total load on soil = 126 tons + say 10% wt. of footing
= 140 tons approximately.

$$\begin{aligned}\text{size of footing} &= \sqrt{\frac{140}{3}} = 6.82 \text{ ft.} = 7'-0'' \text{ say} \\ &= 84'' = a\end{aligned}$$

(b) Depth for safe punching stress.

$$4c \times D \times Sp = p(a^2 - c^2)$$

$$84 \times D \times 150 = 13.7(84^2 - 21^2)$$

$$D = 23''$$

Take total depth of footing as 30'', the column bars being 1'' ϕ

(The effective depth may be taken as 27'')

(c) Bending moment.

$$R = \frac{21}{84} = .25 \qquad k = 1.27 \text{ from graph}$$

$$M = \frac{(126 \times 2240) \times 84}{24} \times 1.27 = 1250000 \text{ inch lbs.}$$

$$\begin{aligned}\text{effective width of footing} &= c + 2D + \frac{1}{2}(a - c - 2D) \\ &= 21 + 54 + \frac{1}{2}(84 - 21 - 54) \\ &= 79\frac{1}{2}'' = 80 \text{ inches.}\end{aligned}$$

$$d \text{ for B.M.} = \sqrt{\frac{1250000}{126 \times 80}} = 11.5'$$

$$A_t = \frac{1250000}{18000 \times .87 \times 27} = 3 \text{ sq. inches.}$$

use 10 Nos $\frac{3}{4}$ '' ϕ bars both ways.

Details of column footings for columns in Chapter 8 are given in Tables 9 (a) and 9 (b).

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9.3 DESIGN TABLES.

Table 9-a
SQUARE FOOTINGS

($f_c = 750 \text{ lbs./in.}^2$ $f_s = 18000 \text{ lbs./in.}^2$ $m = 15$)

Ref No of Column	$\frac{1}{2}$ Ton \square Ft.					1 Ton \square Ft.				
	a	D	Concrete C.Ft.	Steel Bars	Lbs.	a	D	Concrete C.Ft.	Steel Bars	Lbs.
C1a	5'-0"	13"	25.83	6 $\frac{3}{8}$ "	25	5'-7"	13"	11.0	5 $\frac{3}{8}$ "	16
C2a	6'-0"	14"	36.10	10 $\frac{3}{8}$ "	55	6'-8"	14"	17.88	8 $\frac{3}{8}$ "	32
C3a	7'-0"	18"	48.44	9 $\frac{3}{8}$ "	51	7'-0"	18"	25.56	8 $\frac{3}{8}$ "	30
C3a	7'-6"	14"	47.77	14 $\frac{1}{8}$ "	87	5'-3"	14"	24.10	10 $\frac{3}{8}$ "	46
C3b	7'-9"	18"	50.22	13 $\frac{3}{8}$ "	84	5'-6"	18"	30.62	9 $\frac{3}{8}$ "	42
C3c	8'-0"	21"	52.89	13 $\frac{1}{8}$ "	86	5'-9"	21"	35.76	8 $\frac{1}{2}$ "	40
C4a	8'-3"	15"	59.81	11 $\frac{1}{8}$ "	132	5'-9"	15"	50.27	14 $\frac{3}{8}$ "	70
C4b	8'-4"	18"	68.69	17 $\frac{1}{8}$ "	168	6'-0"	18"	32.98	11 $\frac{3}{8}$ "	56
C4c	8'-9"	21"	81.80	16 $\frac{3}{8}$ "	188	6'-3"	21"	43.66	11 $\frac{1}{8}$ "	58
C4d	8'-9"	24"	88.95	14 $\frac{3}{8}$ "	101	6'-3"	24"	47.50	9 $\frac{1}{2}$ "	48
C5a	9'-0"	21"	103.45	18 $\frac{1}{8}$ "	182	7'-0"	21"	53.58	10 $\frac{1}{4}$ "	106
C5b	10'-0"	21"	108.62	14 $\frac{1}{2}$ "	202	7'-0"	21"	55.38	9 $\frac{1}{2}$ "	88
C5c	10'-3"	24"	123.64	18 $\frac{3}{8}$ "	412	7'-3"	24"	64.39	12 $\frac{1}{8}$ "	72
C5d	10'-6"	24"	129.54	15 $\frac{1}{4}$ "	224	7'-6"	24"	68.61	10 $\frac{1}{2}$ "	110
C6a	11'-6"	21"	143.23	22 $\frac{1}{8}$ "	362	8'-3"	21"	76.22	14 $\frac{1}{2}$ "	169
C6b	11'-6"	27"	167.90	16 $\frac{1}{2}$ "	262	8'-3"	27"	89.74	12 $\frac{1}{2}$ "	114
C6c	12'-0"	27"	182.00	12 $\frac{5}{8}$ "	318	8'-6"	27"	95.00	13 $\frac{1}{8}$ "	160
C7a	12'-6"	21"	168.60	18 $\frac{1}{2}$ "	406	8'-9"	21"	85.66	12 $\frac{3}{4}$ "	237
C7b	12'-9"	24"	190.12	16 $\frac{3}{8}$ "	450	9'-0"	24"	98.27	11 $\frac{3}{8}$ "	229
C7c	13'-0"	24"	197.37	17 $\frac{3}{8}$ "	486	9'-3"	24"	103.42	12 $\frac{3}{4}$ "	229
C8a	13'-3"	24"	203.64	18 $\frac{3}{8}$ "	524	9'-3"	24"	104.21	12 $\frac{1}{4}$ "	229
C8b	13'-6"	24"	213.00	14 $\frac{3}{4}$ "	600	9'-6"	24"	108.56	14 $\frac{3}{8}$ "	306
C8c	13'-9"	24"	220.68	14 $\frac{1}{4}$ "	600	9'-9"	24"	114.93	15 $\frac{3}{8}$ "	385
C9a	14'-6"	27"	265.67	15 $\frac{3}{4}$ "	686	10'-6"	27"	144.52	15 $\frac{3}{8}$ "	370
C9b	14'-9"	27"	274.44	16 $\frac{3}{4}$ "	744	10'-6"	27"	144.52	15 $\frac{3}{8}$ "	370
C9c	15'-0"	27"	283.44	16 $\frac{3}{4}$ "	756	10'-6"	27"	144.52	12 $\frac{3}{8}$ "	414
C10a	16'-6"	30"	376.59	17 $\frac{3}{4}$ "	880	11'-9"	30"	192.00	16 $\frac{3}{4}$ "	624

Note: See Table 8-a Chapter No. 8 for Column Reference Number.

COLUMN FOOTINGS

Table 9-a (contd.)
SQUARE FOOTINGS

($f_c = 750 \text{ lbs./in.}^2$ $f_s = 18000 \text{ lbs./in.}^2$ $m = 15$)

Ref. No. of Column	2 Tons/□ Ft.					4 Tons/□ Ft.				
	a	D	Concrete C.Ft.	Steel Lbs.		a	D	Concrete C.Ft.	Steel Lbs.	
C1a	2'-6"	13"	5.56	5 1/2"	12	2'-0"	13"	3.72	5 1/2"	10
C1a	3'-3"	14"	9.72	8 1/2"	24	2'-3"	14"	4.98	8 1/2"	18
C2b	3'-6"	15"	13.12	7 1/2"	23	2'-6"	15"	7.12	7 1/2"	17
C3a	3'-9"	14"	12.77	10 1/2"	34	2'-8"	16"	8.12	10 1/2"	27
C3b	3'-9"	15"	13.07	9 1/2"	31	2'-9"	16"	8.56	9 1/2"	24
C3c	4'-0"	21"	18.75	6 1/2"	30	3'-0"	21"	11.21	6 1/2"	23
C4a	4'-0"	15"	15.80	11 1/2"	40	3'-0"	15"	9.22	11 1/2"	31
C4b	4'-3"	16"	19.44	11 1/2"	42	3'-0"	18"	10.30	11 1/2"	31
C4c	4'-4"	21"	20.23	10 1/2"	34	3'-0"	21"	11.56	10 1/2"	23
C4d	4'-6"	24"	23.94	8 1/2"	30	3'-3"	24"	14.88	8 1/2"	24
C5a	5'-0"	21"	24.87	12 1/2"	53	3'-4"	21"	15.69	12 1/2"	39
C5b	5'-0"	21"	24.87	13 1/2"	57	3'-6"	21"	15.47	13 1/2"	43
C5c	5'-3"	24"	35.64	12 1/2"	54	3'-9"	24"	19.68	12 1/2"	41
C5d	5'-3"	24"	35.64	12 1/2"	54	3'-9"	24"	19.68	12 1/2"	41
C6a	5'-9"	21"	36.13	16 1/2"	79	4'-0"	21"	20.70	16 1/2"	59
C6b	6'-0"	24"	44.56	15 1/2"	79	4'-3"	21"	22.93	17 1/2"	66
C6c	6'-0"	24"	44.56	16 1/2"	79	4'-3"	21"	22.93	18 1/2"	66
C7a	6'-3"	21"	45.95	6 1/2"	116	4'-5"	21"	24.63	18 1/2"	72
C7b	6'-6"	21"	49.39	13 1/2"	126	4'-6"	21"	25.62	13 1/2"	91
C7c	6'-6"	24"	53.92	14 1/2"	135	4'-9"	24"	30.68	14 1/2"	103
C8a	6'-6"	21"	49.37	22 1/2"	122	4'-9"	21"	28.54	22 1/2"	91
C8b	6'-9"	24"	56.33	15 1/2"	150	4'-9"	24"	31.28	15 1/2"	111
C8c	6'-10"	24"	59.72	16 1/2"	164	4'-10"	24"	32.38	16 1/2"	120
C9a	7'-3"	24"	87.49	18 1/2"	192	5'-3"	24"	36.14	18 1/2"	144
C9b	7'-6"	27"	77.79	16 1/2"	177	5'-3"	27"	41.50	16 1/2"	126
C9c	7'-3"	27"	73.14	17 1/2"	182	5'-0"	27"	35.24	17 1/2"	132
C10a	8'-3"	27"	95.81	21 1/2"	393	5'-10"	27"	50.89	21 1/2"	204

Note: See Table 8-a Chapter No. 8 for Column Reference Number.

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Table 9-b
SQUARE FOOTINGS

($f_c = 6000$ lbs./ \square' $f_s = 16000$ lbs./ \square' $m = 15$.)

Ref. No. of Column	1/2 Ton/ \square Ft.					1 Ton/ \square Ft.				
	H	D	Concrete C.Ft.	Steel Bars	Lbs.	H	D	Concrete C.Ft.	Steel Bars	Lbs.
C1	4'-0"	12"	18.36	7 1/2"	28-00	3'-4"	12"	9.50	5 1/2"	15-0
C2	5'-5"	12"	24.12	9 3/4"	40-50	3'-0"	12"	12-1	6 3/8"	18-50
C3a	5'-10"	12"	27.70	12 3/8"	57-00	4'-3"	12"	15-4	10 5/8"	35-6
C3b	6'-4"	15"	26.34	11 1/4"	58-00	4'-0"	15"	19-8	8 3/4"	30-0
C4a	7'-8"	15"	51.37	13 1/2"	170-0	5'-3"	15"	26-4	12 3/8"	51-0
C4b	8'-0"	18"	64.40	13 1/2"	128-0	5'-0"	18"	32-1	8 1/2"	64-0
C4c	8'-2"	21"	74.50	13 1/2"	128-0	5'-9"	21"	32-1	8 1/2"	67-6
C5a	9'-0"	18"	80.58	12 1/2"	235-0	6'-3"	18"	40-7	10 1/2"	80-0
C5b	9'-4"	18"	86.57	12 1/2"	245-0	6'-0"	18"	43-7	10 1/2"	94-0
C5c	9'-6"	21"	98.50	13 1/2"	279-4	6'-9"	21"	56-7	8 3/8"	108-0
C6d	9'-9"	21"	108.58	12 1/2"	242-00	7'-0"	24"	60-4	10 1/2"	160-0
C6A	10'-0"	18"	100.23	13 1/2"	279-36	7'-0"	18"	51-3	9 1/2"	144-6
C6b	10'-4"	21"	117.27	13 1/2"	288-5	7'-4"	21"	61-7	12 1/2"	138-0
C6c	10'-6"	24"	131.95	12 1/2"	262-5	7'-6"	24"	70-4	12 1/2"	128-0
C7a	10'-9"	18"	115.05	13 1/2"	289-6	7'-8"	18"	55-2	11 3/4"	190-7
C7b	10'-10"	21"	122.22	13 1/2"	325-7	7'-8"	21"	64-9	10 1/2"	176-8
C7c	11'-0"	24"	146.77	16 3/8"	343-8	8'-0"	24"	72-2	10 3/8"	188-7
C7d	11'-4"	27"	169.74	15 1/2"	318-2	8'-0"	27"	86-0	10 1/2"	163-7
C8a	12'-0"	21"	170.78	17 3/8"	332-2	8'-0"	21"	87-3	12 3/8"	250-0
C8b	12'-6"	24"	188.28	15 1/2"	607-5	9'-0"	24"	102-6	13 1/2"	267-0
C8c	13'-0"	27"	217.18	15 1/2"	850-0	9'-2"	27"	113-0	12 1/2"	247-6
C8d	14'-0"	27"	252.00	15 1/2"	667-5	10'-0"	27"	132-7	12 1/2"	270-4
C9a	14'-0"	24"	224.00	18 7/8"	968-3	10'-0"	24"	123-2	16 1/2"	360-5
C9b	14'-3"	27"	238.47	18 7/8"	938-4	10'-0"	27"	132-7	16 1/2"	340-3
C9c	14'-6"	24"	247.00	17 1/2"	1075-0	10'-4"	24"	150-0	12 1/2"	448-5
C9d	15'-0"	24"	252.78	18 1/2"	1175-0	10'-6"	24"	164-0	14 1/2"	483-0

Note. See Table 8-b Chapter No. 8 for Column, Reference Numbers.

COLUMN FOOTINGS

Table 9-b (contd.)
SQUARE FOOTINGS

($f_c=600$ lbs./ \square ° $f_s=16000$ lbs./ \square ° $m=15$.)

Ref. No. of Column	2 Tons/ \square Ft.					4 Tons/ \square Ft.				
	a	D	Concrete C.Ft.	Steel Bars	Lbs.	a	D	Concrete C.Ft.	Steel Bars	Lbs.
C1	2'-6"	12"	5.57	6 $\frac{1}{2}$ "	13.50	1'-9"	12"	2.38	6 $\frac{1}{2}$ "	10.6
C2	2'-9"	12"	6.9	6 $\frac{1}{2}$ "	14.42	2'-0"	12"	3.98	6 $\frac{1}{2}$ "	11.25
C3a	3'-0"	12"	8.1	7 $\frac{1}{2}$ "	15.37	2'-2"	12"	4.60	7 $\frac{1}{2}$ "	14.40
C3b	3'-3"	15"	10.7	6 $\frac{3}{4}$ "	16.37	2'-4"	15"	5.60	6 $\frac{3}{4}$ "	13.50
C4a	3'-9"	15"	14.3	9 $\frac{1}{2}$ "	23.70	2'-0"	15"	6.42	9 $\frac{1}{2}$ "	21.93
C4b	4'-0"	18"	18.10	8 $\frac{3}{4}$ "	21.10	2'-10"	18"	10.00	8 $\frac{3}{4}$ "	21.00
C4c	4'-2"	21"	21.43	8 $\frac{3}{4}$ "	21.37	3'-0"	21"	12.37	8 $\frac{3}{4}$ "	21.50
C5a	4'-6"					3'-3"	18"	12.62	10 $\frac{1}{2}$ "	25.75
C5b	4'-9"					3'-4"	18"	13.18	11 $\frac{1}{2}$ "	32.31
C6a	4'-10"	21"	22.1	9 $\frac{1}{2}$ "	64.0	3'-6"	21"	13.80	9 $\frac{1}{2}$ "	48.00
C6d	5'-0"	24"	22.8	8 $\frac{3}{4}$ "	22.25	3'-6"	24"	17.45	8 $\frac{3}{4}$ "	24.00
C6b	5'-0"	18"	27.3	9 $\frac{1}{2}$ "	67.00	3'-8"	18"	13.05	9 $\frac{1}{2}$ "	48.00
C6c	5'-3"	21"	23.7	10 $\frac{1}{2}$ "	77.40	3'-8"	21"	16.61	12 $\frac{1}{2}$ "	35.25
C8c	5'-4"	24"	28.0	10 $\frac{1}{2}$ "	44.70	3'-9"	24"	20.84	10 $\frac{1}{2}$ "	32.50
C7a	5'-6"	18"	22.0	12 $\frac{1}{2}$ "	57.93	3'-9"	18"	16.90	12 $\frac{1}{2}$ "	69.13
C7b	5'-6"	21"	26.6	10 $\frac{1}{2}$ "	61.11	3'-10"	21"	19.55	10 $\frac{1}{2}$ "	56.33
C7c	5'-9"	24"	23.3	9 $\frac{1}{2}$ "	76.40	4'-0"	24"	23.20	9 $\frac{1}{2}$ "	55.00
C7d	5'-9"	27"	47.3	9 $\frac{1}{2}$ "	76.00	4'-2"	27"	27.20	9 $\frac{1}{2}$ "	37.00
C8a	6'-2"	21"	47.4	12 $\frac{1}{2}$ "	109.3	4'-4"	21"	25.10	12 $\frac{1}{2}$ "	79.66
C8b	6'-4"	24"	53.1	11 $\frac{1}{2}$ "	101.5	4'-6"	24"	29.62	11 $\frac{1}{2}$ "	74.55
C8c	6'-6"	27"	60.6	12 $\frac{1}{2}$ "	113.3	4'-9"	27"	35.62	12 $\frac{1}{2}$ "	65.33
C8d	6'-6"	27"	60.6	12 $\frac{1}{2}$ "	113.3	5'-0"	27"	35.50	12 $\frac{1}{2}$ "	69.55
C9a	7'-0"	24"	81.6	12 $\frac{1}{2}$ "	195.5	5'-0"	24"	35.25	12 $\frac{1}{2}$ "	145.60
C9b	7'-0"	27"	82.2	12 $\frac{1}{2}$ "	195.5	5'-0"	27"	35.50	12 $\frac{1}{2}$ "	145.60
C9c	7'-4"	24"	69.1	12 $\frac{1}{2}$ "	203.8	5'-2"	24"	37.32	12 $\frac{1}{2}$ "	149.6
C9d	7'-6"	24"	72.0	12 $\frac{1}{2}$ "	208.0	5'-4"	24"	39.34	12 $\frac{1}{2}$ "	158.9

Note: See Table 8-b Chapter No. 8 for Column, Reference Numbers.

CHAPTER 10
RETAINING WALLS

CONTENTS

10.1 Small Retaining Walls.

10.2 Example.

Charts and Graphs.

CHAPTER 10

RETAINING WALLS

10.1 SMALL RETAINING WALLS.

Small retaining walls upto 15'-0" are mostly of cantilever type. Retained materials like sand, gravel, earth, etc. exert on the retaining structure pressure of much the same nature as ordinary fluids. The intensity of this pressure (w_e) depends upon the weight (w), angle of repose (ϕ) and angle of surcharge (α) of the material and is given by the formula.

$$w_e = w \cos \alpha \frac{\cos \alpha - \sqrt{\cos^2 \alpha - \cos^2 \phi}}{\cos \alpha + \sqrt{\cos^2 \alpha - \cos^2 \phi}} = w k.$$

when there is no surcharge i.e. when $\alpha = 0$. This reduces to

$$w_e = w \frac{1 - \sin \phi}{1 + \sin \phi} = w k$$

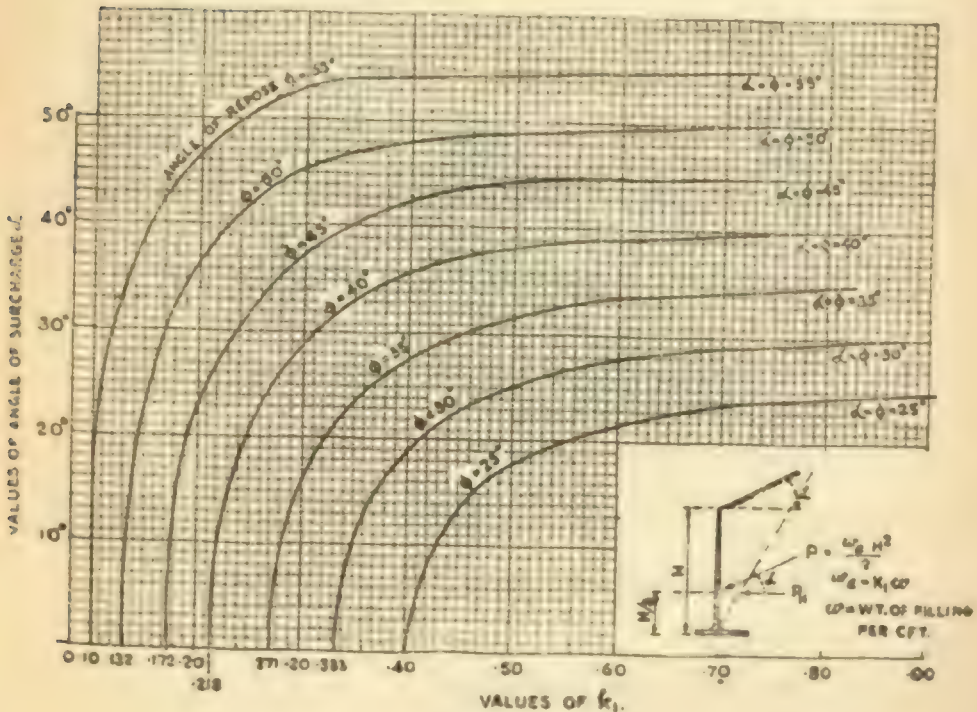


CHART 10-1.

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Chart No. 10-1 gives the values of k for different values of ϕ and α and Table No. 10-a gives the values w and ϕ for various filling materials.

In case of a cantilevered retaining wall it is necessary to see that:

- (a) the stem, heel and toe are adequately reinforced for B.M. and shear
- (b) the overturning moment is less than the stabilizing moment
- (c) the pressure on the ground is within safe limits
- (d) the wall is safe against sliding

Charts 10-2 to 10-6 may be used with advantage for preliminary designs which can subsequently be modified slightly by exact calculations.

10.2 EXAMPLE.

Find approximate dimensions and reinforcement for a cantilever retaining wall 12' high over the ground level with level fill weighing 110 lbs. 'c.ft. and with angle of repose of 30°.

$$we, \text{ from chart 10-1} = .33 \times 110 = 37 \text{ lbs.}$$

$$\begin{aligned} \text{overturning force } P \} &= 4500 \text{ for } we=40 \text{ and } H=15 \\ \text{(from chart 10-3)} \} &= 3700 \text{ for } we=30 \text{ and } H=15 \end{aligned}$$

$$\therefore \text{ for } we=37 \text{ and } H=15 \quad P=4170 \text{ lbs.}$$

$$\begin{aligned} \text{effective depth of stem (from chart 10-2) for } H=14'-0'' \\ = 13' \end{aligned}$$

and $AT=1.25\phi$ i.e. $\frac{3}{4}\phi$ @ 4" c.c. for $we=37$ (by interpolation)

$$\text{assume } B = .5 \times 15 = 7\frac{1}{2} \text{ ft.}$$

$$W = 110 \times 5 \times 15 = 8250 \text{ lbs.}$$

$$\begin{aligned} M \text{ overturning} &= 21200 \text{ ft. lbs. (by interpolation)} \\ &\text{(from chart 10-4)} \end{aligned}$$

$$M \text{ stabilizing} = \frac{5}{2} \times W = 20500 \text{ lbs. ft. (factor of safety 2)}$$

$$\text{Try } B=9'$$

$$\text{then } W = 110 \times 6 \times 15 = 9900 \text{ lbs.}$$

RETAINING WALLS

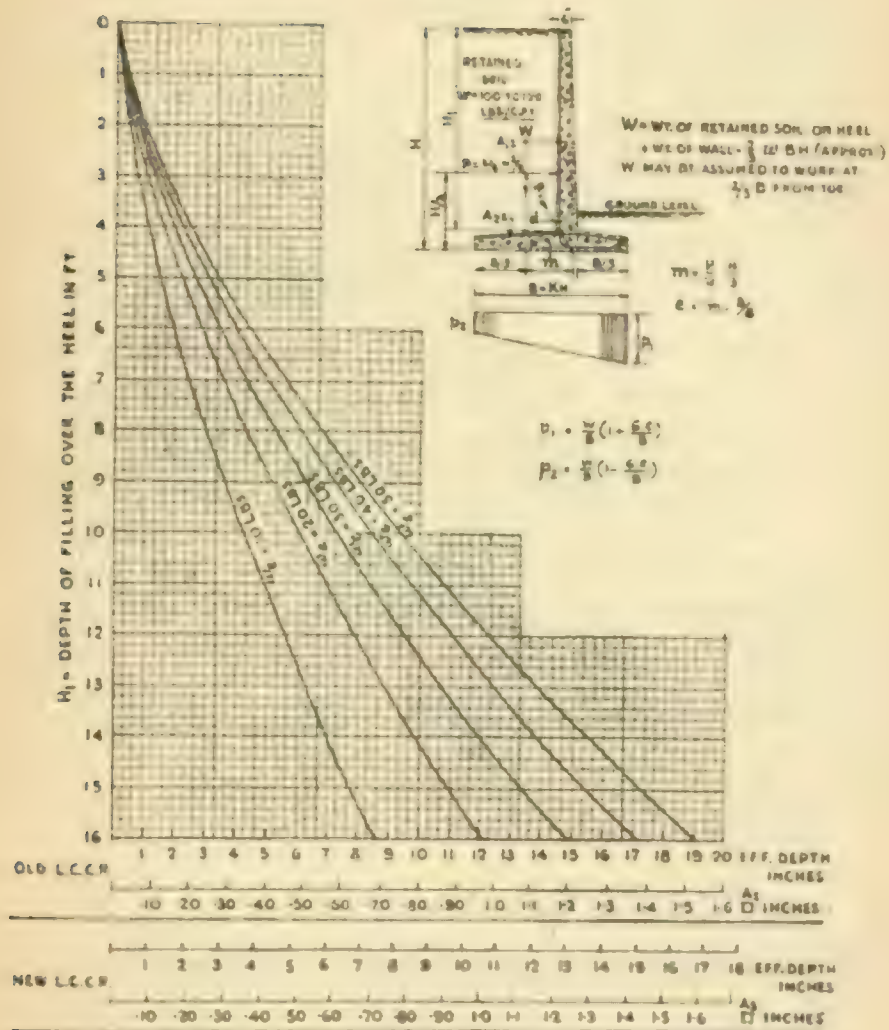
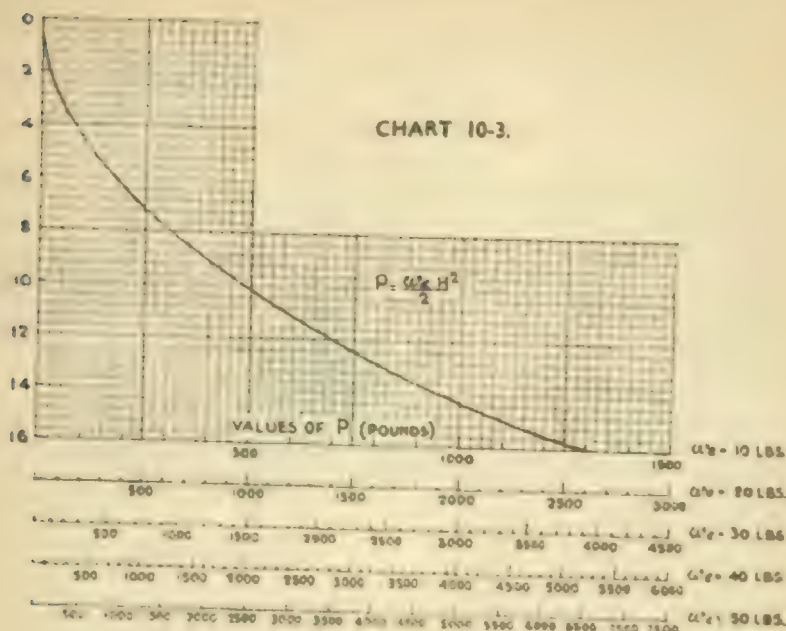


Chart 10-2.

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and stabilizing mt = $9900 \times 3 = 29700$ ft. lbs.

Frictional force = $\mu W = .7 \times 9900 = 6930$ lbs.

which is more than P.

$$m = P/W \times H/3 = \frac{4170}{9900} \times 5 = 2.1 \text{ ft.}$$

$$e = 3 + 2.1 - 9/2 = .6$$

$$p_1 = \frac{9900}{9} \left(1 + \frac{6 \times .6}{9} \right) = 1100 + 1.4 = 1540 \text{ lbs./ft.}$$

$$p_2 = \frac{9900}{9} \left(1 - \frac{6 \times .6}{9} \right) = 1100 - 1.4 = 660 \text{ lbs./ft.}$$

moment in heel for 15' height = 20500 ft. lbs. (from chart 10-5)
and 5' span

$$d = \frac{20500}{126} = 12.7'' \text{ max. say } 15'' \text{ overall.}$$

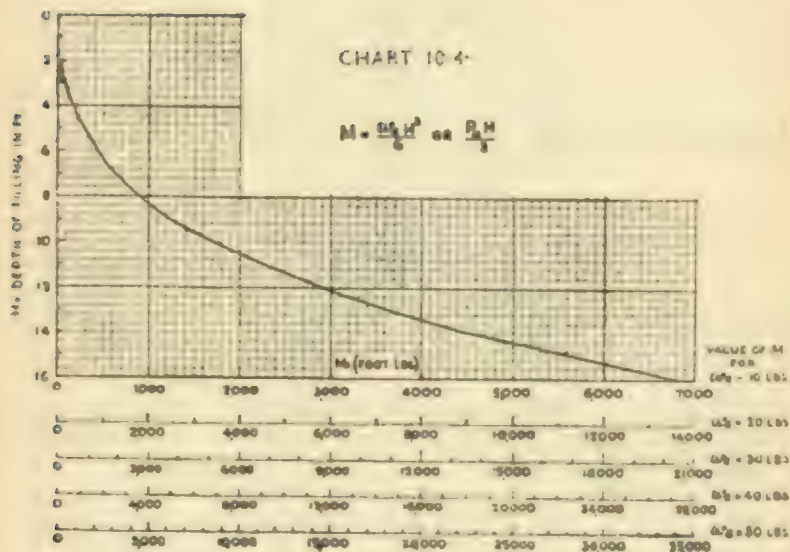
$$A_T = \frac{20500}{18000 \times .87 \times 12.7} = 1.05'$$

RETAINING WALLS

$$\text{moment in toe} = \frac{1540 \times 3^2}{2} = 6900 \text{ ft. lbs.}$$

$$\text{At for } 15\frac{1}{2}' \text{ depth} = \frac{6900 \times 12}{18000} = .87 = 15.5$$

$$= .34 \square' \text{ i.e. } \frac{1}{3}'' \phi @ 10''$$



Note:

The above chart gives the Bending Moment caused in the vertical member of a cantilever retaining wall due to different values of earth pressure.

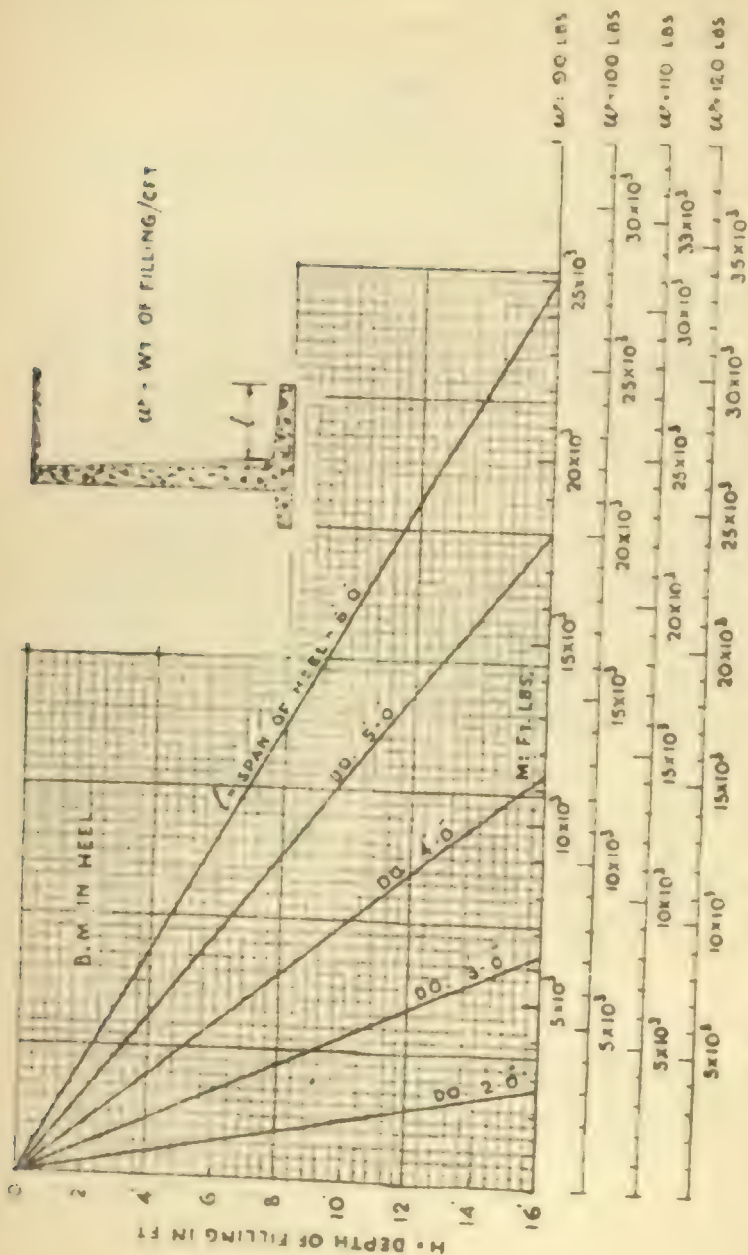


CHART 10-5.

RETAINING WALLS

From these approximate details accurate calculation in which W includes the weight of wall, and in which the point of application of W etc. is correctly calculated can be carried out, and final details worked out accurately.

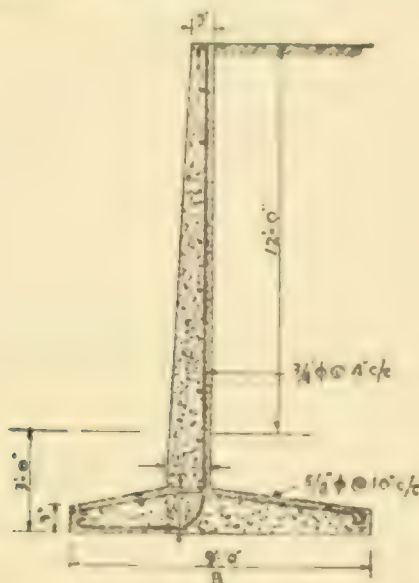


Table 10-a

Material	w (lbs/cft.)	ϕ (degrees)
Sand dry	90 to 100	30
.. moist	100 to 110	35
.. wet	110 to 125	25
Vegetable earth dry	90 to 100	30
-do- moist	100 to 110	45
-do- wet	110 to 120	15
Gravel	90	40
Rubble stone	100 to 110	45
Gravel & Sand	100 to 110	25 to 30
Clay dry	120 to 140	30
.. moist	120 to 160	45
.. wet	120 to 160	15
.. mud	105 to 120	0
Ashes	40	40

CHAPTER 11
CIRCULAR TANKS
CONTENTS

11.1 General.

11.2 Illustrative Example.

CHAPTER 11

CIRCULAR TANKS

11.1 GENERAL.

The pressure of water at a depth of h ft. is 62.5 h lbs. per sq ft. In case of a circular tank the tension in the tank walls caused by the water pressure is therefore $\frac{62.5hD}{2}$ lbs. in a ring one foot high, of diameter D ft. and situated at a mean depth of h ft. below the surface. The cross sectional area of steel rings to be provided in this strip is $\frac{62.5hD}{2 \times 12000}$ sq. inches.

The walls of all tanks are, however, restrained at the base being monolithic with the floor and the walls assume the shape shown in sketch below when the tank is filled with water.



Deflection of Tank Walls.

In such a case the water pressure at the bottom is entirely resisted by the cantilever action of the vertical wall which is subjected to tensile stress on the inner face. In case of shallow tanks of large diameter, the tendency of the walls is to act more

CONCRETE ENGINEERS' HANDBOOK

like vertical cantilevers and hoop stresses are small, whereas in cases of deep tanks of small diameter, hoop stresses are more and cantilever action is very small.

The enclosed charts give

- (a) Capacity of tanks in gallons for various heights and diameters (Chart No. 11-1).
- (b) Position of maximum hoop tension (Chart No. 11-2).
- (c) Amount of maximum hoop tension (Chart No. 11-3).
- (d) Amount of restraint moment (Chart No. 11-4).

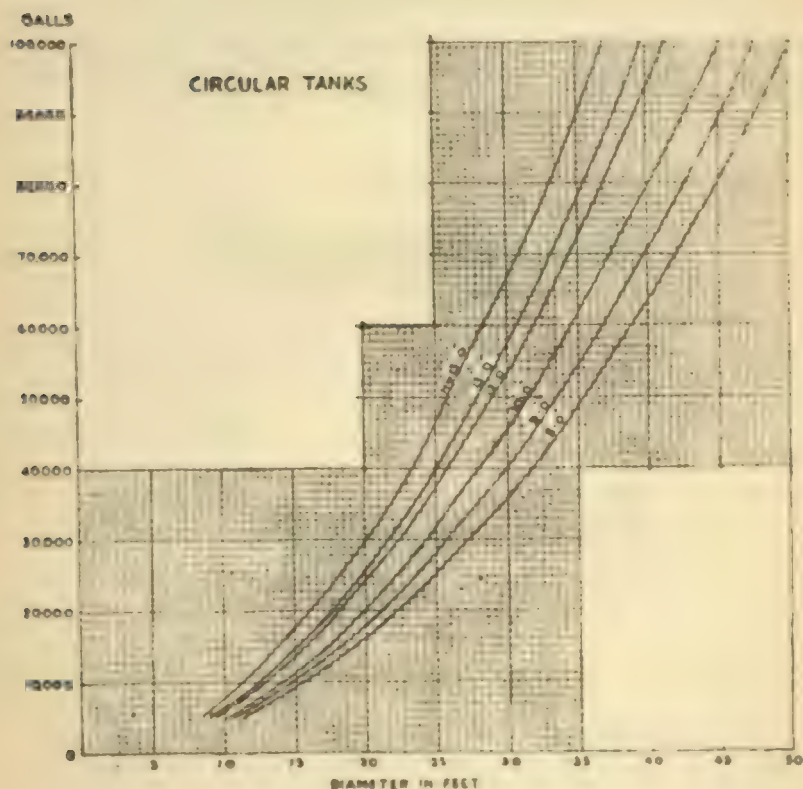
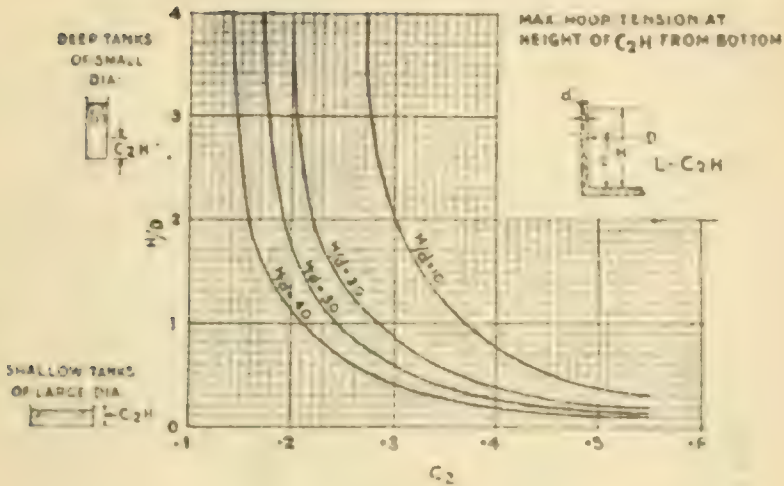


Chart 11-1.

CIRCULAR TANKS

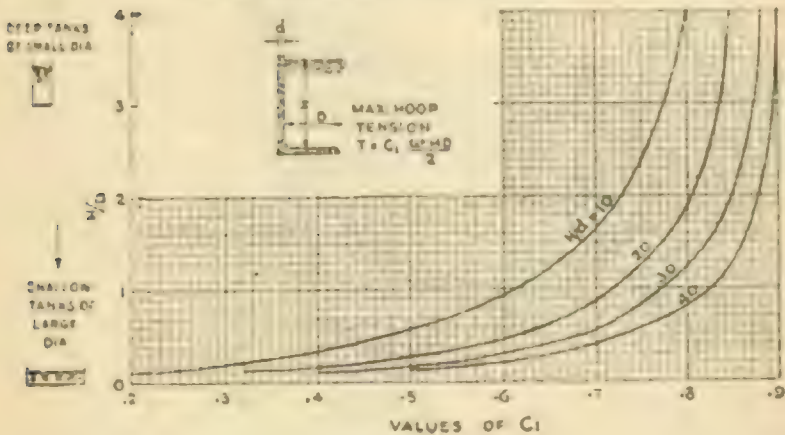
CYLINDRICAL TANKS

POSITION OF MAX. HOOP TENSION.

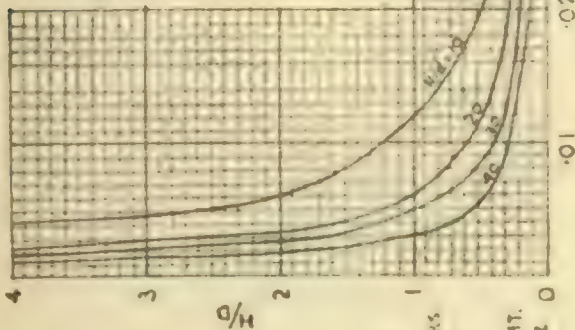


CYLINDRICAL TANKS

AMOUNT OF MAXIMUM HOOP TENSION

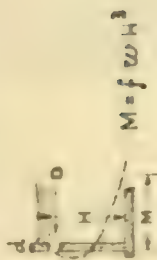


DEEP TANKS } CANTILEVER
WITH SHALLOW DIA. } MOMENT NEGLECTIBLE.



CIRCULAR TANKS

VALUE OF RESTRAINT MOVEMENT.



$$M = f w H^3$$

SHALLOW TANKS
WITH LARGE
DIA
CANTILEVER MT.
CONSIDERABLE.

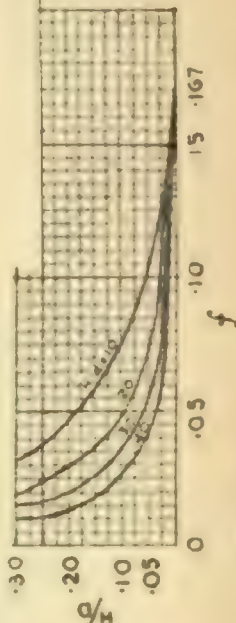
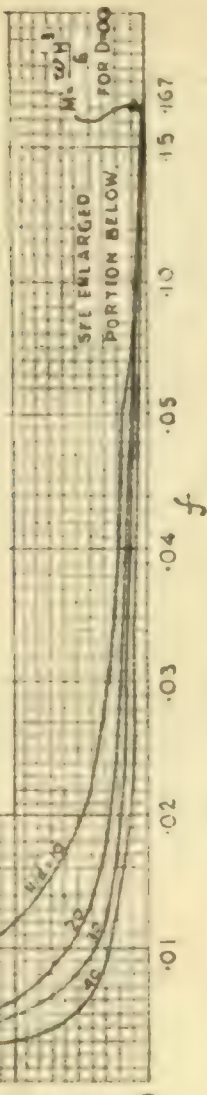


Chart 11-4.

CIRCULAR TANKS

Table 11-a gives detail of tanks of different capacities and sizes.

Table No. 11-a.

Ht. of Water ft. Capacity in Gals.	15					12				
	D	d	L	AM	AV	D	d	L	AM	AV
100,000	87	10	6-30	-83	-65	60	9	5-64	-60	-30
75,000	82	9	5-55	-60	-33	55-5	8	5-30	-64	-36
50,000	78	8	5-00	-70	-25	50	7	4-6	-50	-21
30,000	70 $\frac{1}{2}$	7	4-20	-56	-21	42 $\frac{1}{2}$	7	4-2	-45	-25
10,000	41 $\frac{1}{2}$	7	3-50	-35	-10	15	6	3-6	-28	-16

Ht. of Water ft. Capacity in Gals.	10					8				
	D	d	L	AM	AV	D	d	L	AM	AV
100,000	45	8	8-7	-52 -54	-33	50	7	60	-35	-27
75,000	39	7	4-9	-49 -52	-32 -32	42 $\frac{1}{2}$	7	5-2	-35	-27 -26
50,000	32 $\frac{1}{2}$	6	4-2	-41	-26	35 $\frac{1}{2}$	6	3-8	-32	-25 -23
30,000	25	6	3-9	-30	-21 -22	20	6	3-5	-28	-19
10,000	15	6	3-2	-27	-14	16	6	3-2	-19	-12

11.2 ILLUSTRATIVE EXAMPLE.

Find the stresses in the walls of a circular tank with 10' depth of water and of diameter 25 ft.

Assuming the thickness d of walls as 6"

$$H/d = \frac{10}{.5} = 20 \quad \text{and} \quad H/D = \frac{10}{25} = .4$$

From charts we have:

(a) position of maximum hoop tension

$$L = C_2 H = .4 \times 10 = 4 \text{ ft. above base.}$$

(b) Maximum hoop tension

$$T = C_1 \frac{WH}{2} D$$

$$= .59 \times 62.5 \times 10/2 \times 25 = 4700 \text{ lbs.}$$

(c) Restraint Moment

$$f WH^3 = 0.014 \times 62.5 \times 10^3 \text{ ft. lbs.}$$

$$= 10,500 \text{ inch lbs.}$$

Reinforcement:

$$A_H \text{ (for hoop stress)} = \frac{4700}{12000} = .39 \text{ sq. ins. } \frac{1}{2}'' \phi \text{ @ } 6'' \text{ c.c.}$$

A_v (for restraint moment)

with $\frac{1}{2}'' \phi$ bars and 1" cover

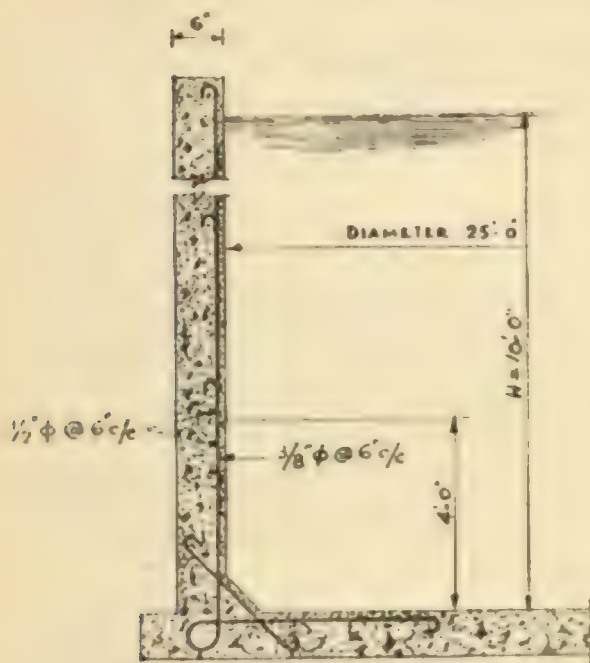
$$\text{effective depth} = 6 - 1.25 = 4.75'$$

$$\text{Lever arm} = .85 \times 4.75'$$

CIRCULAR TANKS

$$A_v = \frac{10500}{12,000 \times .85 \times 4.75} = .22 \text{ sq. ins. approximately}$$

$3/8" \phi @ 6" \text{ c.c.}$



Section of Tank.

CHAPTER 12

DIFFERENT KINDS OF CONCRETE

CONTENTS

- 12.1 Colloidal Concrete or Colcrete.
 - 12.2 Prepacked Concrete.
 - 12.3 Shot Concrete (Gunite).
 - 12.4 Prestressed Concrete.
 - 12.5 Saw Dust Concrete.
 - 12.6 Light Weight Concrete.
 - 12.7 Precast (Prefabricated Concrete).
 - 12.8 Air-entrained Concrete.
-

CHAPTER 12

DIFFERENT KINDS OF CONCRETE

12.1 COLLOIDAL CONCRETE OR COLCRETE.

This is a particular process of making concrete in which stone aggregates which are already laid in position are bound together by cement and sand grout mixed in a special type of mixer. A grout of cement, sand and water mixed in the usual manner is not sufficiently fluid to penetrate between the interstices of the aggregates and produce a dense concrete. Cement particles being very fine are difficult to wet as they cling to each other and are also surrounded by a thin film of air. The surface areas of cement and sand are 80% and 19% respectively of the surface area of all the constituents of concrete. Hence, if these two constituents are efficiently wetted, it is easy to get proper quality of concrete. The special type of machine for mixing the grout is shown below (Fig. 12-1).

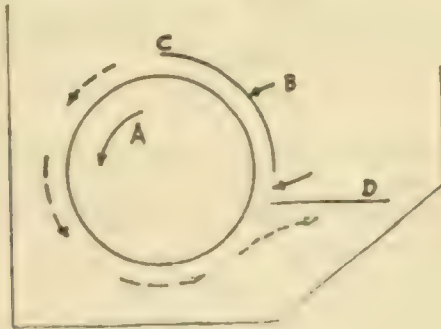


Fig. 12-1.

The roller A about 8" diameter rotating anticlockwise at 1200 r.p.m. draws in grout through a volute shaped cavity between the drum and the cowl B. The cowl is hinged at C so that the gap at the end of the volute may be adjusted. A knife-edged plate D nearly touches the roller immediately below the back edge of the cowl and cuts off the liquid and directs it to the back of the tank so that complete mixing is secured. After each mixing the grout is tipped into a sump from where it is removed by a pump. In some machines two stage mixing is

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done. Cement and water are mixed first and then sand and cement paste subsequently.

Colloidal concrete is very economical as just the required quantity of grout enough to fill in the voids in the coarse aggregate is used. For 1 cubic yard of colloidal concrete only 3 cwts of cement are required as against 5 cwts for usual 1:2:4 mix. Colcrete is very useful in road and runway construction.

12.2 PREPACKED CONCRETE.

The principle of this method of making concrete is the same as above, but instead of using mechanical method of effecting thorough mixture of cement, water and sand, certain chemicals are added to the grout. Cheecol is one such chemical compound.

12.3 SHOT CONCRETE.

12.3.1 DEFINITION.

Cement and sand mortar applied by air pressure is commonly called gunite. Actually such concrete is termed Shotcrete in general and "gunite" is only a trade name for the product of Cement Gun Company.

12.3.2 USES.

Gunite is used for many purposes, the most important being:—

- (a) Repairing masonry or concrete structures.
- (b) Waterproofing.
- (c) Construction of water tanks.
- (d) Lining of canals and reservoirs. (Two inches thick gunite is used on brick pitching and three inches of earth slopes.)
- (e) Protection of steel from fire, corrosion, etc.
- (f) Roof and rib protection in mines.
- (g) Walls and roofs etc. of buildings.

12.3.3 PROPERTIES OF GUNITE.

Gunite walls for building are generally 2" thick and are shot on chicken netting stretched against plywood forms. Roofs of buildings are 2 to 3 inches thick. Gunite is used for r.c. domes also.

DIFFERENT KINDS OF CONCRETE

Strength @ 28 days—6000 lbs./sq. inch average.

Modulus of elasticity—4,670,000 lbs./sq. inch.

W/C ratio required—.25 to .30 (by weight)

Density— $\frac{3}{4}$ " gunite slab could stand 700' head of water

1 $\frac{1}{2}$ —do— 1600' —do—

12.3.4 NOTES ON SPECIFICATIONS FOR GUNITE WORK.

- a. Sand should be of fineness modulus 2.4.

The following grading is recommended:

passing No. 4 sieve	98—100%
8 ..	70— 95%
16 ..	60— 85%
30 ..	45— 65%
50 ..	15— 35%
100 ..	0— 5%

Sand should be slightly moist (3 to 8% moisture).

- b. Air Pressure: 35 lbs./sq. inch for 100' long hose.
Increase 5 lbs for every additional 50 ft.
- c. Water Pressure: Should be 15 lbs more than the atmosphere.
- d. Material should be shot at right angles to the surface. Loose sand deposits should be removed. A thin edge should be left at each day's work.
- e. The following points to be attended to in case of various works:

Steel encasing: fix 2" x 2" mesh wire netting at about $\frac{3}{4}$ " from the surface. Remove paint, rust, etc. and apply gunite 1:3 mix by volume.

Floors: apply 1:3 gunite in one coat upto $\frac{3}{4}$ " thickness. For greater thickness apply in 2 coats the final coat being always more than one inch.

Wall slabs and panels: The thickness to be 1 $\frac{1}{2}$ " upto 4' span and 2" upto 7' span. The steel fabric reinforcement should not be more than 4" mesh and the area should be 3% of wall cross-section in each direction.

Waterproofing of walls: Clean and sand-blast the surface and apply $\frac{1}{2}$ " gunite 1:3 mix.

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12.3.5 DESIGN DATA FOR GUNITE.

Assumptions: Ultimate compressive stress.

1:3 mix—4100 lbs/sq. inch.

1:2½ mix—4800 —do—

f_c	f_s	n	j	p	q
1500	20000	.43	.86	.016	276
1800	20000	.47	.84	.021	359
1200	16000	.43	.86	.016	221
1500	16000	.48	.84	.023	305

(Value of modular ratio is 10)

12.4 PRESTRESSED CONCRETE.

12.4.1 PRINCIPLE OF PRESTRESSED CONCRETE.

Principle of prestressed concrete is to introduce internal stresses in the concrete, of nature opposite to those caused by the design load. Hence when the design load operates, the resultant stresses in the concrete are very low.

12.4.2 ADVANTAGES OF PRESTRESSED CONCRETE.

- (a) Economy: spans above 100 ft. are not economical in ordinary R.C. work since so much of concrete is wasted in portion below the neutral axis.
- (b) It is possible to use high tensile steel reinforcement which cannot be used in ordinary R.C. because of necessity to limit the width of minute cracks in the tensile zone to .02 inches.
- (c) The danger of rusting of reinforcement due to atmospheric action in unfavourable areas is entirely eliminated.

12.4.3 METHODS OF PRESTRESSING.

There are two methods:

- (a) Prestretched bonded method.
- (b) Post-stretched bondless method.

In (a) high tensile steel reinforcement is placed in position and stretched with the help of yokes, hydraulic jacks and abutments. The calculated tension is induced in the wires and concrete is filled into the mould of the prestressed concrete member and allowed to set. When the concrete is sufficiently strong, the tension of the wire is released. The steel while contracting induces compression in the concrete, being bonded to the concrete.

DIFFERENT KINDS OF CONCRETE

In (b) high tensile steel is placed in the moulds of the prestressed concrete member but is prevented from coming in contact with the concrete being encased in sheaths. The prestressing reinforcement consists of cables made of high tensile steel wires, laid in one or more rings round a core. After the concrete is placed and allowed to attain its normal strength, the high tensile wires are stretched by means of special jacks. The wires are then anchored to the two ends of the beams or structural member by special anchorages. The compression in the concrete is developed through these anchorages instead of through bond between steel and concrete as in method (a).

12.4.4 THEORY.

The prestressing compression being applied eccentrically produces in the section concerned stresses equal to $\frac{F}{A} \pm \frac{Fy'y}{I}$. These stresses when combined with the tension and compression due to dead and live load bending give the resulting stresses as shown in Fig. 12-2.

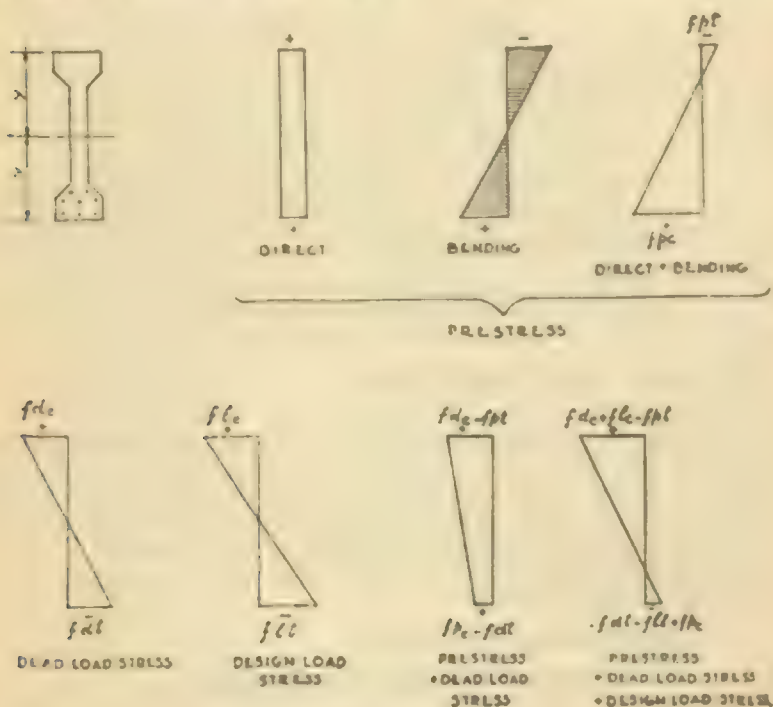


Fig. 12-2

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The induced prestressing force is reduced to some extent due to shrinkage of concrete, creep in concrete, plastic flow of steel reinforcement and compression of concrete due to prestressing.

12.4.5 USES OF PRESTRESSED CONCRETE.

Prestressed concrete is being used for various structural items such as bridges, large span roofs, precast roofing joists, railway sleepers, tanks, pressure pipes, etc. etc. The following statements will give some idea about the comparative dimensions and economic possibilities of prestressed concrete.

- (1) Prestressed concrete girders *vs* steel joists.

For the same Loading

- (a) Prestressed concrete girders are twice the weight of steel joists.
- (b) Prestressed concrete girders are one and a half times deeper than steel joists.

- (2) R.C.C. *vs* Steel Girders

Steel in ordinary R.C.C. Girders is 10 per cent of that used in steel joists.

- (3) Prestressed concrete *vs* R.C.C. Girders

- (a) Steel required in prestressed concrete girders is 25% of that required in R.C.C. Girders, i.e., $2\frac{1}{2}\%$ of that required in steel joists.
- (b) Concrete in prestressed concrete girders is 50% of that required in ordinary reinforced concrete girders.

12.5 SAW DUST CONCRETE.

Mixture of cement and saw-dust can serve as a useful building material with some limitations. The strength of saw-dust concrete is uncertain and must be determined by tests. However, it may be taken 10 to 20% the strength of normal concrete. The principle use of saw-dust concrete is as an insulating material and for special purposes. The results of tests on saw-dust concrete are given below:—

Building Research Station U.K.

1 : 2 mix gave 1190 lbs/sq. in. @ 7 days

1 : 4 " 92 "

DIFFERENT KINDS OF CONCRETE

New Zealand : (with *Pinus insignis* as aggregates)

1 : 2 mix gave 1190 lbs/sq. in.

1 : 4 „ 725 lbs/sq. in.

The following results are also experimentally found with pine wood saw-dust.

Mix	Comp. strength @ 7 days ultimate.	Density
1 : 2	1100	75
1 : 3	500	49
1 : 4	150	41
1 : 6	110	40
1 : 1½ sand : 1½	1300	100

The extractable materials in saw-dust upset the hardening of cement. This can be prevented by using dust from soft woods or by using 20% of lime or 5% of calcium chloride in the mix. It is advisable to first immerse the saw-dust in boiling water for about 10 minutes and then wash it freely with water. This should be repeated second time, by mixing 2% ferric sulphate in the boiling water and washing the dust again. Saw-dust concrete absorbs water and hence expands and shrinks on getting wet and dry. This can be prevented by coating the units with water resisting substances and using certain percentage of sand as aggregate.

Consistency of the concrete should be such that the mix compacts itself. The following amounts of water are suggested :

Cement	Saw-dust (slightly damp)	Water
94 lbs.	1 cft.	5.5 gallons
	2 cft.	5.9 gallons

The finish should be smooth but even, heavy trowelling should not give cement skin on the top.

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12.6 LIGHT WEIGHT CONCRETE.

Is frequently used in making precast blocks, etc., to keep down the weight of the units. Research has shown that it is possible to make concrete of low cement content, with excellent workability, sufficient strength and adequate heat insulation and effect appreciable economy in structural load of a building.

12.6.1 METHODS.

Lightweight concrete is made by

- (a) Using light and porous aggregate such as breeze, pumice, etc.
- (b) By adding to the cement slurry, containing little or no aggregate, an aerating agent which causes the paste to foam so that the set material contains a certain proportion of air.

12.6.2 LIGHT AGGREGATES.

These are of three types.

- (a) Natural: such as pumice, breeze, etc.
- (b) By-products: such as Blast-furnace slag, coke, breeze, cinders, saw-dust, etc. etc.
- (c) Processed aggregates such as
Exfoliated Vermiculite—a type of mica expanded by heat.

Sintered diatomite—a processed diatomite with soft chalky particles.

Perlite—an expanded perlite composed of frothy particles.

Expanded clay.

Sintered fly ash—a processed material resulting from the combustion of powdered fuel in steam power plants.

12.6.3 AERATED CONCRETE.

Hydrogen gas bubbles are generated in a mix containing lime or cement by incorporation of finely divided aluminium or zinc powder about 0.1% of cement. The cellular structure produced in this way is retained after the cement has set and a lightweight product obtained thereby. Sometimes a foaming agent is used, instead of the metal powder, and the mix is whipped up in a special mixer to a fine foam. The weight of aerated cement is 40 to 60 lbs per c.ft.

DIFFERENT KINDS OF CONCRETE

Properties of Light Weight Concrete

Material	Mix	Wt. Lbs/cft.	Compressive strength lbs./sq. in.	Transverse strength lbs./sq. in.	Shrinkage %	Thermal conductivity.
Pumice Concrete	1 : 6	45—70	200—550	100—150	·04—·08	1·4 B.t.h U
-do-	1 : 10					1·1
Clinker Concrete	1 : 6	50—105	150—450	75—250	·03—0·20	2·6
-do-	1 : 10					2·3
Foamed Slag Concrete	1 : 6	80—95 60—65	300—500	200—300	0·06—0·06	1·5—2·2
Cellular Concrete	1 : 12	37—60	300—500	100—240	0·06—0·18	1—2
Ballast Concrete	1 : 2 : 4	140—150	3000—5000	300—600	0·08—0·04	7·0

12.7 PRECAST (PREFABRICATED) CONCRETE.

Precast (Prefabricated) Concrete is getting popular day by day.

12.7.1 ADVANTAGES.

- (a) Economy in form work.
- (b) Possibility of standardization and employment of machinery for manufacture.
- (c) Controlled weather conditions.
- (d) Use of experienced and skilled workmen.
- (e) Temperature effects in the structure are negligible due to many construction joints.
- (f) Defective components can be easily rejected.

12.7.2 DISADVANTAGES.

- (a) Repeated handling may break the units.
- (b) The problem of connecting various units properly is difficult.

12.7.3 REQUIREMENTS.

Precast concrete units must be strong and at the same time light. It is, therefore, necessary to use light-weight concrete in case of non-structural units. Structural units are made either hollow or flanged or are in prestressed concrete so as to cut down the quantity of concrete. It is also necessary to use special methods of consolidation and curing such as vibration, shocks, spinning, steam or electric curing, etc. The concrete also is

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very carefully designed and made. Typical sections of structural precast concrete units are shown in Fig. 12-3 (on facing page).

12.7.4 APPLICATIONS.

Precast concrete is used for numerous purposes, the following being only a typical list of most important items:

Floors: Channel beams, hollow beams, T-beams, I-beams, etc.

Foundation: Sockets for wooden or steel column
plates —do—
pedestals —do— etc.
piles —do—

Building frames: Portals, gabled frames, etc.

Building units: Hollow and solid blocks, lintels, wall panels (Hollow or solid), window and door sills, cornices, string courses, chimneys, trusses, roofing tiles, etc.

Bridges: Bridge girders, slabs, arch voussoirs.

Miscellaneous: Pipes, transmission line poles, garden furniture, drains, silos, tanks, railway sleepers, etc.

12.8 AIR-ENTRAINED CONCRETE. (See Para 1.1.2.8)

It is possible to cause in the concrete the inclusion of millions of microscopic bubbles during the process of mixing by using a small amount of certain chemicals either in the mixing water or in the cement. Each bubble of air is encased in a hard glazed shell formed by the surface active force generated by the chemical reaction. Thus the formation of the usual capillary channels by which the water enters the concrete, is prevented and there is no possibility of disintegration of the concrete by freezing and thawing or by leaching. The air bubbles give additional workability permitting smaller w/c ratio and consequently better strength. The segregation of the concrete is prevented due to reduction of w/c ratio and action of the air bubbles. It is also possible to give a better finish to the concrete and improve the surface texture by preventing sand streaking. Vinsol resin is the most common air-entering agent. Several proprietary air-entraining agents are available in the market.

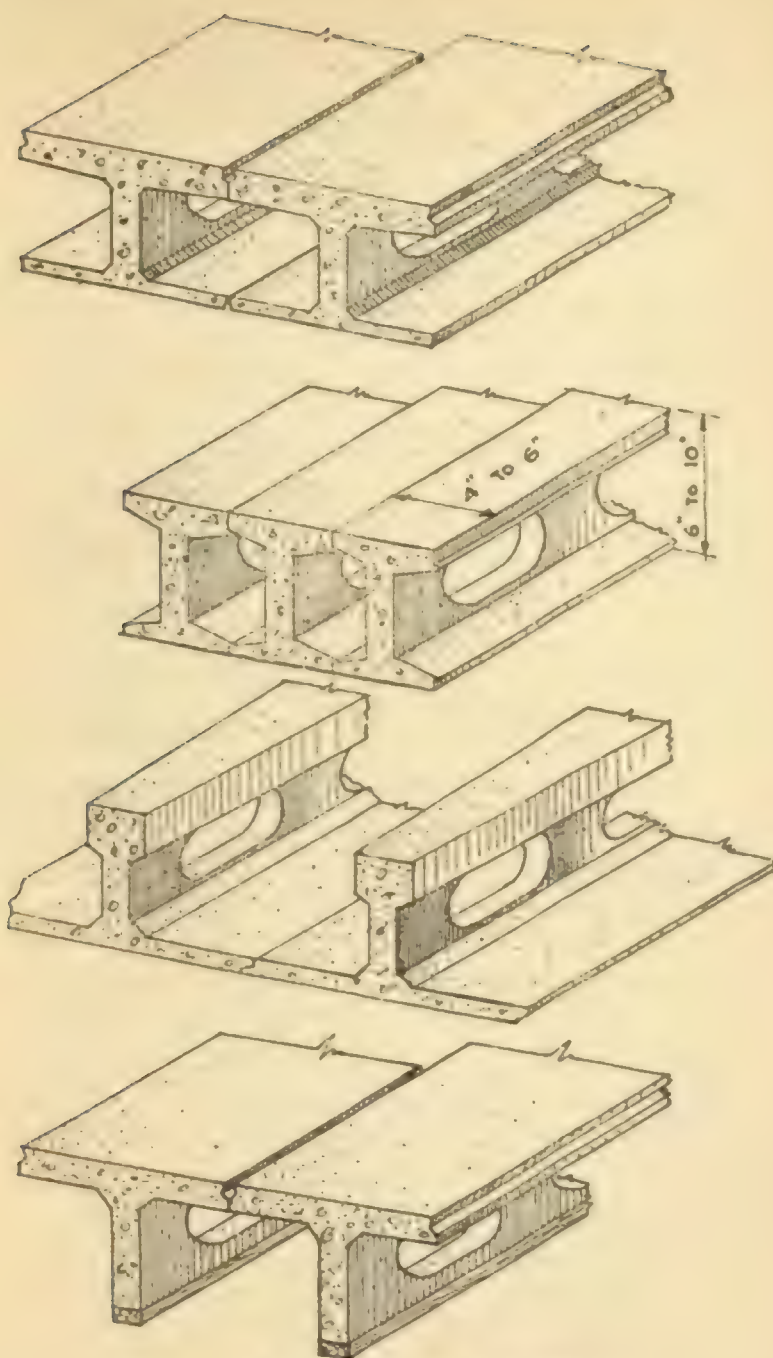


Fig. 12-3. Precast Floor Systems.
I Beam, Rapid Floor Rail System and T Section.

CHAPTER 13
MISCELLANEOUS INFORMATION
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- 13.1 Soil Cement.
 - 13.2 Asbestos Cement.
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 - 13.4 Cement Admixtures.
 - 13.5 Waterproofing of Concrete.
 - 13.6 Effects of Acids, Oils and Salts on Concrete.
 - 13.7 Protective Treatments.
-

CHAPTER 13

MISCELLANEOUS INFORMATION

13.1 SOIL CEMENT.

Soil cement is a simple intimate mixture of soil with measured amounts of Portland cement and water, compacted to high density. It is mostly used for pavement work.

13.1.1 REQUIREMENTS OF SOIL CEMENT WORK.

- (a) Adequate cement content.
- (b) Proper moisture content.
- (c) Proper density.

The above requirements are determined by tests before starting the work.

- (a) Cement content: Cement acts as a binder and by chemical action with water converts the soil cement mixture into a hardened mass.
- (b) Water is required to get the necessary workability for the mass to ensure proper compaction and for the hydration of the cement.

13.1.2 TESTS FOR SOIL CEMENT WORK.

Before starting the work it is necessary

- (a) to analyse the soil.
- (b) to determine how much cement and water should be added to the soil.
- (c) to find out the density to which a soil cement mixture should be packed.

(a) Soil is examined for gradation and for any material harmful to cement. The best gradation found by experiment is as follows:—

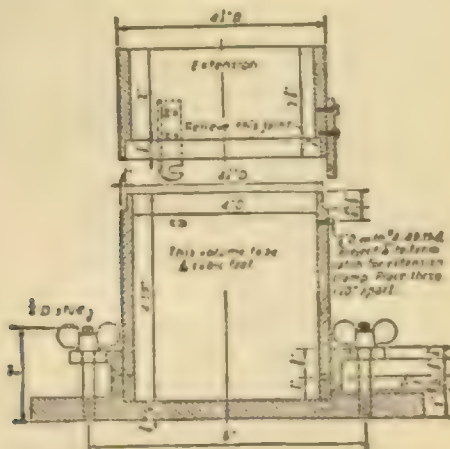
<u>Sieve designation</u>	<u>% by weight passing square mesh sieve.</u>
No. 3	100
No. 4	55-100
No. 40	15-100
No. 200	0- 50

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All soil can be broadly divided into three groups.

- (1) Sandy and gravelly soils with about 10 to 35% silt and clay combined. These are quite suitable for soil cement work.
- (2) Sandy soils deficient in fines like beach sands, wind blown sands, etc. are also suitable but present difficulties in packing and finishing.
- (3) Silty and clayey soils also make satisfactory soil cement, but those containing higher clay are difficult to pulverise.

(b) & (c) The approximate minimum moisture content and the approximate minimum volume to which a soil cement mixture should be packed are the optimum moisture and the maximum density. This is determined by means of a special mould and rammer. The soil cement is packed in three layers of equal thickness into a 1/30 c.ft. moisture density mould (also called Procter Mould) with collar attachment.



Cylindrical mould for Moisture-Density Test.

Fig. 13-1.

Each layer is compacted by 25 uniformly spaced vertical blows of a 3½ lb. rammer having a 2" diameter striking face and a free fall of 12". The thickness of the layer is controlled so that the third layer extends over the top of the mould into the collar extension, a distance of about ½ inch. After removing the collar, the soil cement is trimmed to the exact size of the mould.

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after which the assembly is weighed. The damp weight of the compacted material at different moisture contents is determined in this way, and after determining the moisture content of each test, the dry weights are calculated and then plotted against moisture contents to form a moisture density curve. The optimum moisture content is that at which the greatest dry density is obtained in the test. This density is referred to as the maximum density and is the approximate minimum density to use in soil cement construction. The cement content required to harden the soil will depend upon the nature of the soil and varies from 7 to 16%. It is therefore necessary that the soil on a particular job be tested to determine the safe economical quantity of cement that should be added to it to harden it properly. This is determined by the wetting and drying test. Specimens are alternately subjected to wetting and drying cycles and the loss of material due to two firm strokes of a wire scratch brush is noted.

13.13 CONSTRUCTION.

There are two methods followed, viz. :—

- (a) mixed in place with heavy duty field cultivators, gang ploughs, rotary speed mixers, etc.
- (b) mixed with a travelling type mechanical mixer.

The former is in common use for pavements, etc. and hence described below. The latter is used for cheap type of house construction.

(a) Pavements, roads, etc.

- (i) Initial preparation of the site is made and grades, etc. fixed properly.
- (ii) Pulverization: A depth of about 5½" is ripped up by means of pulverizing equipment. Offset disc harrows with 24 to 26 inches discs and rotary speed mixers are then used to break up the soil lumps. During this pulverization a 3 or 4 bottom plough is used to assist in cutting a level sub-grade for exposing the edge of the pavement by throwing the material towards the centre, and for bringing up the lumps from the bottom.
- (iii) Spreading cement: This is done by hand or by mechanical spreaders upon the area. By accurate calculation the cement bags are spotted properly.
- (iv) Dry mixing: When cement spread is completed the mixing of cement and soil is carried out by

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means of spring tooth field cultivators, rotary litters, three or four bottom gang ploughs, offset harrows, etc.

- (v) **Watering:** It is often desirable to prewet the soil the day before, if the soil is very dry. For excellent mixing conditions the moisture contents of the said soil should be two or three percentage below the optimum moisture for the soil at the time the cement is spread. Water is added in as large increments as the equipment and the soil will permit. One gallon of water per sq. yd. per application should be sufficient for most soil. After adding 75% of the required water content, samples of the mixed material are examined. Soil cement when at optimum moisture is just moist enough to moisten the hands and it can pack in the hands to form a tight cast.
- (vi) **Compaction:** This is done by sheepsfoot rollers. When the feet of the roller are at 2" to 3" from the surface, a motor grader is used for preliminary shaping. Again the sheepsfoot rollers continue packing until about 1" of loose material remains. At this stage again the motor grader is used to get the final shape. During this interval small quantity of water may be added. The surface compaction planes formed by the last sheepsfoot rolling are removed by a spike tooth harrow.
- (vii) **Finishing:** This is done by means of a pneumatic tyre roller.
- (viii) **Curing:** This is done by moist earth covering or waterproof paper.

13.2 ASBESTOS CEMENT.

Asbestos cement is a combination of asbestos fibres and Portland cement. Asbestos is an infusible, tough and flexible mineral in fibrous form. The fibres are made of extremely minute threads about $\frac{1}{1000}$ m.m. in diameter. Suitable type of asbestos for asbestos cement products is found in Russia, Canada and South Africa. Neat Portland cement is mixed with about 15% of asbestos fibres in such a way that all fibres are thoroughly coated with fine cement. This composition is kept under great hydraulic pressure until it sets. The asbestos fibres act in the same way as steel reinforcement used in R.C.C.

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work, but the mixture possesses the great advantage that it is more resilient. It has been proved to possess indefinite durability and great resistance to transverse and tensile stresses. The cement in these products is reinforced in a most effective manner by an intricate network of carefully blended and opened asbestos fibres.

13.3 CEMENT GROUTING.

Grouting is always done under high or low pressure. High pressure grouting is done at pressures above 100 lbs/sq. inch. There are various methods of pressure grouting such as

(a) Fluid or Pump grouting.

(b) Plastic grouting (air pressure grouting).

(a) is the older method of grouting. Mixtures with a consistency of soft fluid mud are used for injection and usually neat Portland cement or very rich cement and sand mixtures are employed. Since the amount of water used is excessive, the grout has got very little cementing value. A reciprocating pump is used for this work.

(b) Cement mortar, or small aggregate concrete with a slump of 6 to 8 inches are injected by pneumatic pressure by means of special machinery which consists of an air compressor and a grouting chamber as shown in Fig. 13-2. By proper manipulation of the various valves and the by-pass pipe it is possible to charge and discharge the grouter and also agitate the grout.

Grouting is used for various purposes, such as—

(a) Soil stabilization.

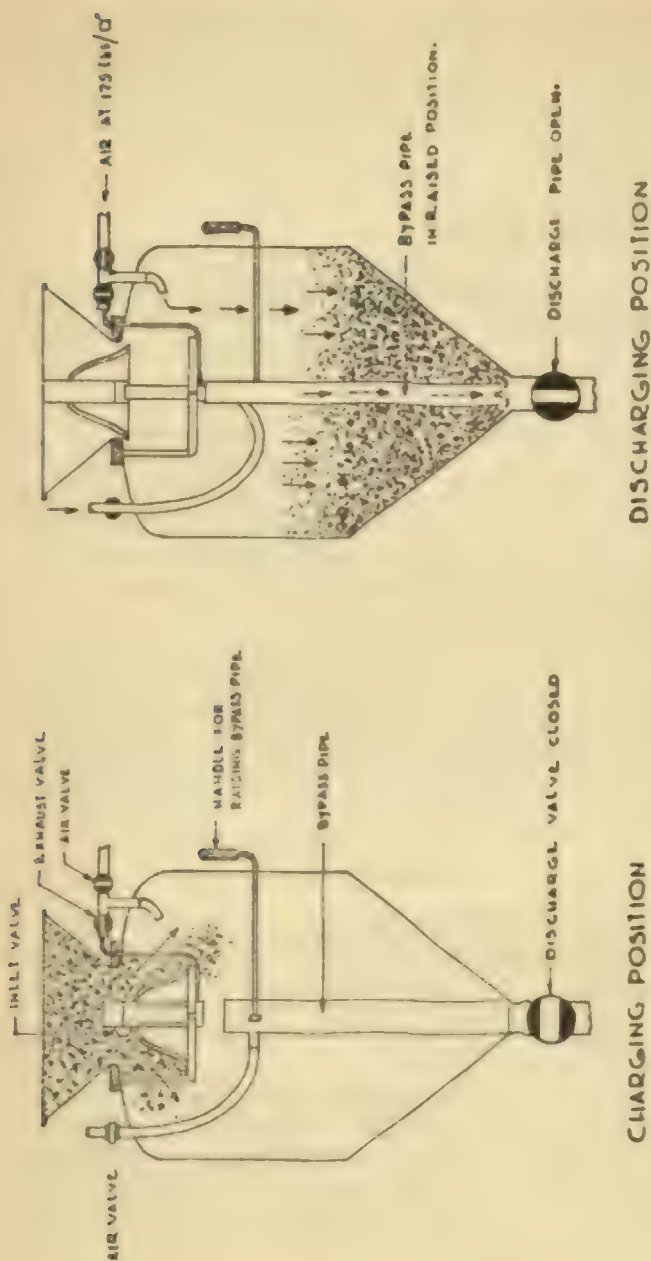
(b) Solidification of fractured, porous or fissured rock.

(c) Restoration of completed structures by strengthening the foundations.

(d) Sealing of rock strata, gravel or other water-logged ground formations. Preventing contamination of well water from polluted water oozing through porous strata, etc.

(e) Dry pack concrete construction.

(f) Cast in place pile work, etc.



Grouting Machine.

Fig. 13-2.

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13.4 CEMENT ADMIXTURES.

Admixtures consist of powdered materials to be added to the concrete during its preparation to improve its quality. Most of these are more or less inert and have an indirect effect on the quality of concrete. Admixtures can be classed as of three types, physical, cementacious and pozzolanic.

13.4.1 PHYSICAL ADMIXTURES.

When water is added to the cement, heavier particles of cement settle down and finer particles and water go to the top. The segregation of cement particles is prevented by these admixtures which help in improving the texture of the concrete.

13.4.2 CEMENTACIOUS ADMIXTURES.

These behave more or less like cement and give a richness to the concrete mixture.

13.4.3 POZZOLANIC ADMIXTURES.

Pozzolanic admixtures: These have no cementing value of their own, but they react with the products of hydration of cement to form compounds adding to the strength of the concrete mixture.

Admixtures commonly used are quicklime, slaked lime, diatomeaceous earth, bentonite, glue, and salts acting as dispersing agents.

13.5 WATERPROOFING OF CONCRETE.

13.5.1 NECESSITY.

Portland cement concrete has a high resistance to permeation of water when it is gauged with correct quantity of water. In practice, however, we usually add more water to increase the workability and thus increase the voids space in concrete, making it permeable. In order to get water-tight concrete, it is necessary to use clean, well graded, non-porous aggregates with sufficient sand to fill in the void and correct amount of mixing water.

13.5.2 METHODS OF WATERPROOFING.

- (a) Use of internal waterproofers.
- (b) Surface treatments.

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(a) These consist of materials added to cement or concrete. They are available in form of finely ground inert substances such as chalk, diatomaceous earth, silica, dolomitic lime or talc intended to improve the plasticity of the mix and thereby reduce the voids. These are usually employed in conjunction with substances of hydrophobic character e.g. calcium and aluminium soaps. Liquid waterproofers contain substances capable of reacting with a second solution or with cement to form an insoluble product. Examples of this type of solutions are alkali silicates, calcium chloride, zinc sulphate and ordinary soap. Integral waterproofers generally contain calcium chloride soaps, hydrated lime, etc.

(b) These are: Asphalt emulsions, iron salammoniac compounds, cement washes, silicate of soda, boiled linseed oil, gelatinous pastes, etc.

13.5.3 A FEW WATERPROOFING COMPOUNDS LIKELY TO BE AVAILABLE IN BOMBAY.

Name of Product	Sole Agents in India
Sealocrete	McKenzies Ltd., Sewri, Bombay.
Ironite	Heatley & Gresham Ltd., 9, Forbes Street, Fort, Bombay.
Tretol	J. C. Gammon Ltd., Hamilton House, Ballard Estate, Bombay.
Impermo (A.P.C.M.)	The Anglo-Thai Corporation Ltd., Ewart House, Bruce Street, Bombay.
Compo-Seal	Robert Ingham Clark & Co., Lakshmi Building, Sir P.M. Road, Bombay.
Aquella	Turner Hoare & Co. Ltd., Gateway Building, Apollo Bunder, Bombay.
Pudlo	Richardson & Cruddas, Byculla Ironworks, Parel Road, Byculla, Bombay.
Sika	William Jacks & Co., Hamilton House, Ballard Estat., Bombay.

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Name of Product	Sole Agents in India
Metarock	Gannon Dunkerley & Co. Ltd., Chartered Bank Building, Fort, Bombay.
Cico (Che-Ko)	Structural Waterproofing Co., 21-1, Davar Road, Ballygunge, Calcutta.
Cemexo	The Unique Waterproofing Co., 28/A Debendra, Calcutta.
Hydrol	H. S. Cox & Co. Ltd., 24 Rampart Row, Bombay 1.
C.C. Case Hardening	—do— —do—
Sodium Silicate	Imperial Chemical Industries, Imperial Chemical House, Dougall Road, Ballard Estate, Bombay.
Visek	Marshall & Sons Ltd., Marshall's Building, Ballard Estate, Bombay.

13.6 EFFECTS OF ACIDS, OILS AND SALTS ON CONCRETE.

Protective Treatments Recommended, Where
Required—Directions for their application.

13.6.1 GENERAL CONSIDERATIONS.

The industrial application of this problem is of great importance in numerous cases where chemicals, oils, and various other industrial liquids are kept in storage in reinforced concrete tanks.

The protective treatments recommended are based, as they must be, on the assumption that the concrete is of a suitable quality, which means a well cured, dense, water-tight concrete. This requires:

- (a) Low water-cement ratio, not to exceed 6 gal. of mixing water per sack of cement.
- (b) Suitable workability, to avoid mixes so harsh and stiff that honeycomb occurs, and those so fluid that water rises to the surface.

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- (c) Thorough mixing, at least one minute after all materials are in the mixer, or until the mix is uniform.
- (d) Proper placing, spacing or vibration to fill all corners and angles of forms without segregation of materials—avoid construction joints.
- (e) Adequate curing, protection by leaving forms in place, covering with wet sand or burlap and sprinkling. Concrete to be kept wet and above 50°F. for at least the first week. Not to be subject to hydrostatic pressure during this period.

Many solutions such as brines and salts, which have no chemical effect on concrete, may crystallize upon loss of water. It is especially important that concrete subject to alternate wetting and drying of such solutions be very dense and non-absorbent. If the concrete is porous it will absorb the solution. Since the crystals require more space than the liquid, they exert considerable pressure which may be sufficient to break down the concrete. Salt solutions corrode steel more rapidly than plain water. In structures which are to be subject to frequent wetting and drying by these solutions it may be advisable to provide some surface coating such as sodium silicate, linseed oil or one of the varnishes as an added precaution.

13.6.1 SURFACE TREATMENTS.

Materials are available for almost any degree of protection required on concrete. The more common methods of treatment are indicated in the table, the numbers in the table corresponding to the following numbered paragraphs in which the necessary instructions are given:

(1) Magnesium Fluosilicate or Zinc Fluosilicate.

The treatment consists of two or more applications. First, a solution of about 1 lb. of the fluosilicate crystals per gallon of water is used. For subsequent applications about 2 lb. of crystals per gallon of water is used. Large brushes are convenient for applying on vertical surfaces, and mops on horizontal areas. Each application should be allowed to dry; after the last has dried, the surface should be brushed and washed with water to remove crystals which have formed. The treatment densifies and hardens the surface by chemical action. Fluosilicates are available through dealers in chemicals.

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(2) Sodium Silicate (commonly called water glass).

This is quite viscous and must be diluted with water to obtain penetration, the amount of dilution depending on the quality of the silicate and the density of the concrete. Silicate of about 42.5 deg. Baume gravity diluted in proportions of 1 gal. with 4 gal. of water makes a good solution. It may be applied in two or three or more coats, allowing each coat to dry thoroughly. On horizontal surfaces it may be poured on and then spread evenly with brooms or brushes. Scrubbing each coat with water after it has hardened provides a better condition for application of succeeding coats. For tanks and similar structures progressively stronger solutions are often used for the succeeding coats.

(3) Linseed Oil.

Only boiled linseed oil should be used. Applied hot, it gives better penetration. Two or three coats may be applied, allowing each to dry thoroughly before the next application. The concrete should be well cured and seasoned before the first application. Linseed oil is sometimes applied after the magnesium fluosilicate treatment, providing a good coating over a hardened surface.

(4) Cumar.

Cumar is a synthetic resin soluble in xylol and similar hydrocarbon solvents. A solution consisting of about 6 lb. of Cumar per gallon of xylol with $\frac{1}{2}$ pint boiled linseed oil makes a good coating. Two or more coats should be applied. Concrete should be fairly dry. The cumar should be powdered to aid dissolving. It is available in grades from dark brown to colourless.

(5) Varnishes.

Any varnish can be applied to dry concrete. High grade varnishes of the spar, china-wood oil, or bakelite types give good protection against many substances. Good varnishes may contain natural or synthetic resins. Two or more coats should be applied.

(6) Bituminous or Coal Tar Paints, Tar and Pitches.

These are usually applied in two coats, a thin priming coat to insure bond and a thicker finish coat. Concrete must be dry and dust-free. Finish coat must be carefully applied to insure continuity and avoid pin holes. Surface should be touched up where necessary.

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(6) Bituminous Enamels.

This is suitable protection against relatively strong acids. It does not resist abrasion at high temperatures. Two materials are used, a priming solution and the enamel proper. The priming solution is of thin brushing consistency and should be applied to dry, dust-free concrete, touching up any uncoated spots before applying the enamel. When primer has dried to a slightly tacky state, it is ready for the enamel. The enamel usually consists of a bitumen with a finely powdered siliceous mineral filler. The filler increases the resistance to flowing and sagging at elevated temperatures, and to abrasion. The enamel should be melted and carefully heated until it is fluid enough to brush. The temperature should not exceed 375°F. When fluid it should be mopped on quickly, as it sets and hardens rapidly.

Bituminous paints and enamels are made by a number of companies.

(8) Bituminous Mastic.

This is used chiefly for floors on account of the thickness of the layer which must be applied, but some mastics can be troweled on vertical surfaces. Some mastics are applied cold. Others must be heated until fluid. The cold mastic consists of two compositions—the priming solution and the body coat or mastic. The primer is brushed on dry, dust-free concrete. When it has dried to a tacky state, a thin layer—about 1/32" of the mastic is troweled on. When this has dried, successive 1/32" coats of the mastic are applied, until the required thickness has been built up. The mastic is similar to the primer but is ground with sufficient asbestos and finely powdered siliceous material fillers to make a very thick, pasty fibrous mass.

The hot mastics are somewhat similar to the mixtures used in sheet asphalt pavements, but contain more asphaltic binder so that when heated to fluid condition, they can be poured and troweled into place. They are satisfactory only when applied in layers of 1 in. or more in thickness. When ready to lay, the mixture usually consists of about 15 per cent asphaltic binder, 20 per cent finely powdered siliceous mineral filler, and the remainder is sand graded up to 1/4 in. maximum size.

Masties are made by a large number of manufacturers.

(9) Vitrified Brick or Tile.

These are special burnt clay products which are not attacked by acids or alkalis. They must, of course, be laid in

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mortar which is also resistant against the substance to which they are to be exposed. A bed of the mortar is usually placed between the brick or tile and concrete. Some of the acid-proof cements are melted and poured in the joints. Many manufacturers make acid-proof brick and cement.

(10) Glass.

May be cemented to the concrete.

(11) Lead.

May be cemented to the concrete with an asphaltic paint.

(12) Rubber.

One of the largest rubber companies in U.S.A. contracts to treat tanks and other structures with their "Acid-Seal". The material is not for sale to other contractors.

13.7 EFFECT OF ACIDS, OILS AND OTHER PRODUCTS, ON UNPROTECTED CONCRETE, WITH PROTECTIVE TREATMENTS, WHERE REQUIRED.

ACIDS.

Material	Effect on Concrete	Surface treatment
Acetic	Disintegrates slowly	5, 6, 7
Acid waters	Natural acid waters may erode surface mortar, but usually action then stops	1, 2, 3, 4, 5, 6, 7
Carbolic	Disintegrates slowly	1, 2, 3, 5
Carbonic	Disintegrates slowly	2, 3, 4, 5, 6, 7
Humic	Depends on humus material but may cause slow disintegration	1, 2, 3, 4, 5, 6, 7
Hydrochloric	Disintegrates	8, 9, 10, 11, 12
Hydrofluoric	Disintegrates	8, 9, 11, 12
Lactic	Disintegrates slowly	1, 2, 3, 4, 5, 6, 7
Muriatic	Disintegrates	8, 9, 10, 11, 12
Nitric	Disintegrates	8, 9, 10, 11, 12
Oxalic	None	None
Phosphoric	Attacks surface slowly	1, 2, 3, 4, 5, 6, 7
Sulphuric	Disintegrates	8, 9, 10, 11, 12
Sulphurous	Disintegrates	8, 9, 10, 11, 12
Tannic	Disintegrates slowly	1, 2, 3, 4, 5, 6, 7

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SALTS AND ALKALIES

Material	Effect on Concrete	Surface treatment
Carbonates of Ammonia Potassium Sodium	Weak solutions and dry salts will not affect concrete. Strong solutions may cause slow disintegration and concrete should be treated	1, 3, 4, 5, 6, 7
Chlorides of Calcium Potassium Sodium		
Chlorides of Ammonia Copper Iron Magnesium Mercury Zinc	Disintegrates slowly	1, 3, 4, 5, 6, 7

Material	Effect on Concrete	Surface treatment
Fluorides	None except ammonium fluoride	3, 4, 5, 6, 7
Hydroxides of Ammonia Potassium Sodium	Disintegrates	1, 3, 4, 5, 6, 7
Nitrates of Ammonia Calcium Potassium Sodium		
Potassium Perman- ganate	None	None
Silicates	None	None
Sulphates of Ammonia	Disintegrates	8, 9, 10, 11, 12
Aluminum Calcium Cobalt Copper Iron Manganese Nickel Potassium Sodium Zinc	Disintegrates	1, 3, 4, 5, 6, 7

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PETROLEUM OILS

Material	Effect on Concrete	Surface treatment
•Heavy oils below 30° Baume	None	None
•Light oils above 30° Baume	None—Some loss from penetration	1, 2, 3, 5,
Benzine Gasoline Kerosene Naphtha	None—Considerable loss from penetration	1, 2, 3, 5.

•Many lubricating and other oils contain some vegetable oils. Concrete exposed to such oils should be protected as for vegetable oils.

Material	Effect on Concrete	Surface treatment
Coal	Great majority of structures show no deterioration. Exceptional cases have been coal high in pyrites (sulphide of iron) and moisture showing some action but the rate is greatly retarded by deposit of an insoluble film. Action may be stopped by surface treatments	1, 2, 3, 4, 5, 6, 7
Corn syrup	Disintegrates slowly	1, 2, 3, 4, 5, 6, 7
Electrolyte	Depends on liquid. For lead and zinc refining use.	7, 8, 9, 10, 12
Formalin	Aqueous solution of formaldehyde disintegrates concrete.	9, 10, 11, 12
Fruit juices	Most fruit juices have little if any effect as tartaric acid and citric acid do not appreciably affect concrete. Floors under raisin seeding machines have shown some effect, probably due to poor concrete.	1, 2
Glucose	Disintegrates slowly	1, 2, 3, 4, 5, 6, 7
Glycerine	None	None
Honey	None	None
Lye	Same as sodium hydroxide	1, 2, 3, 4, 5, 6, 7

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Material	Effect on Concrete	Surface treatment
Milk	Sweet milk should have no effect but if allowed to sour the lactic acid will attack.	1, 2, 3, 4, 5, 6, 7
Molasses	Does not affect dense, thoroughly cured concrete. Dark, partly refined molasses may attack concrete that is not thoroughly cured. Such concrete may be protected with	2, 5
Nitre	Same as nitrate of potassium	1, 3, 4, 5, 6, 7
Sal ammoniac	Same as ammonium chloride—causes slow disintegration	1, 3, 4, 5, 6, 7
Sal soda	Same as sodium carbonate	1, 3, 4, 5, 6, 7
Salt petre	Same as nitrate of potassium	1, 3, 4, 5, 6, 7
Sauserkraut	Little, if any, effect. Protect taste with.	1, 2
Silage	Attacks concrete slowly	3, 4, 5, 6, 7
Sugar (cane or beet)	No effect on concrete that is thoroughly cured.	None.
Sulphite liquor	Attacks concrete slowly	1, 2, 3, 4, 5, 6, 7
Tanning liquor	Depends on liquid. Most of them have no effect. Tanneries using chromium report no effects. If liquor is acid, protect with	1, 2, 3, 4, 5, 6, 7
Vinegar	Disintegrates (See acetic acid)	1, 2, 3, 4, 5, 6, 7
Washing soda	Same as sodium carbonate	1, 3, 4, 5, 6, 7
Whey	The lactic acid will attack concrete	1, 2, 3, 4, 5, 6, 7
Wine	Many wine tanks with no surface coating have given good results but taste of first batch may be affected unless concrete has been given tartaric acid treatment	For fine wines the concrete has been treated with 2 or 3 applications,* (1 lb. tartaric acid in 3 pints water.) Sodium silicate is also effective. In a few cases tanks are lined with glass-tile.
Wood pulp	None	None.

* of tartaric acid solution.

MISCELLANEOUS INFORMATION

Material	Effect on Concrete	Surface treatment
Alizarin	None	None
Anthracene		
Benzol		
Carborol		
Cumol		
Paraffin		
Pitch		
Toluol		
Xylol		
Carbolineum	Disintegrates slowly	1, 2, 3, 5
Creosote		
Cresol		
Lysol		
Phenol		

VEGETABLE OILS

Material	Effect on Concrete	Surface treatment
Cotton seed	No action if air is excluded. Slight disintegration if exposed to air.	None 1, 2
Rosin	None	None
Almond	Disintegrates surface slowly	1, 2
Castor		
•China-wood		
Cocoanut		
•Linseed		
Olive		
Peanut		
Poppy seed		
Rope seed		
Soy-bean		
Tung		
Walnut		
Turpentine	None—Considerable penetration	1, 2

* Applied in thin coats the material quickly oxidizes and has no effect. Results indicated above are for constant exposure to the material in liquid form.

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FATS AND FATTY ACIDS (Animal)

Material	Effect on Concrete	Surface treatment
Fish oil	Most fish oils attack concrete slightly. Menhaden oil does not.	1, 2
Folio to Lard and lard oil Tallow and tallow oil	Disintegrates surface slowly	1, 2

MISCELLANEOUS

Material	Effect on Concrete	Surface treatment
Alcohol	None	None
Ammonia water (Am. Hydroxide)	Disintegrates slowly	1, 2, 3, 4, 5, 6, 7
Baking soda	Same as sodium bicarbonate—no effect in weak solutions and dry salts. For strong solutions treat concrete.	1, 2, 3, 4, 5, 6, 7
Beer	Beer will cause no progressive disintegration of concrete, but in beer storage and fermenting tanks a special coating is used to guard against contamination of beer	Coating made and applied by a New York Company.
Bleaching powder	Mixtures of calcium chloride and calcium hypochloride do not affect dense concrete.	None
Borax, boracic acid, boric acid	No effect	None
Brine (salt)	No effect on dense concrete. Where subject to frequent wetting and drying of brine provide	1, 2, 3, 4, 5, 6, 7
Buttermilk	Same as milk	1, 2, 3, 4, 5, 6, 7
Charged water	Same as carbonic acid—slow attack	1, 2, 3, 4, 5, 6, 7
Caustic soda	(Sodium hydroxide) Disintegrates	1, 2, 3, 4, 5, 6, 7
Cider	Disintegrates (See acetic acid)	1, 2, 3, 4, 5, 6, 7
Cinders	May cause some disintegration	1, 2, 3, 4, 5, 6, 7

CHAPTER 14
GENERAL DATA, TABLES, ETC.
CONTENTS

Crushing strength of stones.

Strength of lime mortars.

Safe permissible loads on masonry.

Wind pressures.

Water pressures.

Working stresses for timber.

Task work for artisans.

Mensuration.

Properties of circles.

Areas of small circles.

Weights and measures.

Conversion factors.

CHAPTER 14

GENERAL DATA, TABLES, ETC.

Crushing Strength of Stones

	Tons/s.ft.
Granite	1000 to 700
Trap	400
Basalt	1000
Sandstone (Hard)	600
" (Medium)	400
Limestone (Hard)	400
" (Soft)	100
Brick (1st Class)	100
Cement concrete 1 : 2 : 4	180

Strength of Lime Mortars

		3 months	27 months
		Tons/sq.ft.	Tons/sq.ft.
Hydraulic Kankar Lime	1:1	71	107
	1:1½	66	104
	1:2	64	118
	1:2½	52	104
	1:3	46	85
Fat lime	1:2	48	—
—do— Surkhi	2:1:6	59	—
—do— Blacksoil Surkhi	2:1:6	49	—

Safe Permissible Loads on Masonry

	Tons/s.ft
1. Brick in mud	1½
2. Brickbat concrete in lime	2
3. Stone metal concrete in lime	3 to 3½
4. Laterite masonry in lime	2
5. —do— (good quality stone)	3

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	Tons/s.ft.
6. Country brickwork in lime	2 to 3½
7. 1st Class " "	4 to 5
8. C. R. Masonry in lime	3.5 to 7
9. —do— (granite)	5
10. Country bricks in cement	4 to 6
11. 1st Class bricks —do—	8
12. Granite ashlar	15
13. Trap —do—	20
14. Cement Concrete	
1 : 2 : 4	32
1 : 3 : 6	25
1 : 4 : 8	19

Wind Pressures in India & Pakistan.

40 LBs/sq. ft.

Karachi Dist., Cutch and Saurashtra.

20 LBs/sq. ft.

Madras, Vellore, Nellore & Masulipatam Districts.

15 LBs/sq. ft.

Makran, Hyderabad(Sind), Deesa, Ahmedabad, Surat, Bombay, Poona, Ratnagiri, Goa, Belgaum, Karwar, Mangalore, Mercara, Coconada, Vizagapatam, etc.

10 LBs/sq. ft.

For the rest of India and Pakistan.

The above allowance is on safe side.

Wind velocity and pressure.

Nature of wind.	Equivalent velocity miles 1 hour.	Mean wind pressure lbs. per sq. foot.
1. Moderate breeze	15	0.67
2. Fresh breeze	21	1.31
3. Strong breeze	27	2.30
4. Strong gale	50	7.70
5. Whole gale	59	10.50
6. Storm	68	14.00

Water velocity and pressure.

$P=1.8V^2$ for fresh water.

$=1.85V^2$ for salt water.

V —velocity of current in feet/sec.

P —pressure on a plane normal to the current in lbs. per sq. foot.

GENERAL DATA, TABLES, ETC.

WORKING STRESSES FOR TIMBER (lbs. per sq. inch.)

No. 1 Quality.

Name	Young Modulus.	Bending			Shear	Compression					
		A	B	C		Parallel to grain			Perpendicular to grain		
Burmah Teak	1600	2200	2000	1570	125	1700	1580	1230	700	520	420
C. P.	1200	1820	1650	1100	120	1380	1280	1000	670	500	400
Yellow Pine	1630	1740	1580	1240	120	1350	1250	980	400	300	240
Kail	980	950	860	680	110	970	900	700	170	125	100
Deodara	1348	1740	1580	1240	100	1370	1270	990	440	330	260
Sat	1920	2120	1930	1610	175	1510	1400	1090			
Jarrah	1500	2300	2070	1640	..	970	810	630			

No. 2 Quality.

Burmah Teak	1400	1830	1690	1300	115	1380	1230	1000	600	470	380
C. P.	1050	1510	1360	1070	110	1120	1000	810	570	430	360
Yellow Pine	1420	1450	1240	1020	105	1100	980	800	340	270	220
Kail	858	700	680	560	95	790	700	570	140	110	90
Deodara	1170	1440	1275	1020	88	1110	990	810	350	295	240
Sat	1670	1770	1510	1250	150	1230	1090	890			
Jarrah	1200	1910	1640	1350	..	710	630	510			

Note: A Inside location.
B Outside location.
C Wet location.

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DAILY TASK WORK FOR ARTISANS & LABOURERS.

(Working day 8½ hours)

(1) Excavation: (5' lift & 100' lead)

a	earth	75 cft. per man
b	soft murum	50 " "
c	average murum	35 " "
d	hard murum	25 " "
e	soft rock	16 " "
f	hard rock	8 " "

(2) Breaking metal

trap stone	1½" size	10 cft. per man
quartz	-do-	13 " "
laterite	-do-	20 " "
brick	-do-	50 " "

(3) Conveying metal on head

lead	100 ft.	85 cft. per man
	200 "	65 " "
	300 "	50 " "
	600 "	35 " "

(4) Masonry

a	ashlar stone	2 cft. one mason & 1 man
b	coarsed rubble 1st class	9 " " "
	-do- 2nd "	12½ " " "
	-do- 3rd "	20 " " "
c	brick 1st class	17 " " "
	" 2nd "	25 " " "

(5) Plastering

¾" thick cement	33 s.ft. one mason & 1 man
rough cast	90 " " "
pointing	60 " " "

GENERAL DATA, TABLES, ETC.

(6) Flooring

Flagstone (lādi)	30 to 40 sq. ft.
Dressed trap stone	5 "
Cement concrete	30 "

(7) Carpenter

a	Panelled doors 4' × 7'	10 days per piece
b	Plain planked	4 "
c	Glazed windows	6 "
d	Venetianed windows	14 "
e	Teakwood work (framing)	2 cft.
f	-do- (joinery)	1 "
g	Woodwork in Mangalore tiled roof	100 sft.
h	-do- in G.C.I. roof	33 "

(8) Precast concrete works (in steel moulds)

a	Pipes 6' diameter	12 nos.
b	Roofing tiles	90 "
c	Hollow blocks (in hand machine)	100 " (1 mason & 2 coolies)
d	Paving flags	30 "

(9) Cutting and bending reinforcement

$\frac{1}{2}$ " ϕ to $\frac{1}{2}$ " ϕ	2 cwts.
$\frac{1}{2}$ " ϕ	2 $\frac{1}{2}$ "
$\frac{1}{2}$ " ϕ to 2" ϕ	4 "

(10) Erecting formwork

20 s.ft.

(11) Finishing

a	Whitewashing 3 coats	400 s.ft.
b	Distempering	200 "
c	Cement washing 2 coats	400 "

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Mensuration

Circumference of circle	Dia \times 3.1416
Side of an equal square	Dia \times .8862
Side of an inscribed square	Dia \times .7071
Area of a circle	Dia ² \times .7854
Area of a sector	length of arc $\times \frac{1}{2}$ radius
Ellipse	.7854 \times long axis \times short axis
Parabola	Base \times height $\times \frac{1}{2}$
Parallelogram	Height \times base
Trapezium	Sum of parallel sides \times H/2

Volume or surfaces.

Lateral surface of a sphere	$4 \pi r^2$
“ “ cylinder	$2 \pi rh$
“ “ cone	$\pi r h^2 + r^2$
Contents of a sphere	$\frac{4 \pi r^3}{3}$
do cone	$\pi r h^2 + r^2$
do cylinder	$2 \pi rh$
do pyramid	area of base \times perpendicular height $\div 3$

GENERAL DATA, TABLES, ETC.

PROPERTIES OF THE CIRCLE

$$\text{Chord of angle } A = \frac{c}{r}$$

$$\begin{aligned} \text{Versed sine of angle } \frac{1}{2}A &= \frac{h}{r} \\ &= 1 - \cos \frac{A}{2} \end{aligned}$$

$$\text{Area of circle} = \pi r^2 = .7854d^2$$

$$\text{Circumference of circle} = 2\pi r$$

$$\pi = 3.141593 \quad \pi^2 = 9.869604$$

$$\text{Arc length } abc = rA \quad (A \text{ in radians})$$

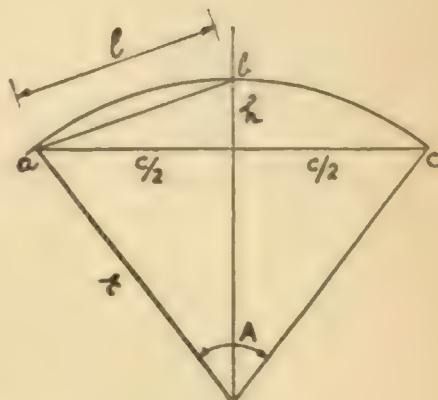
$$\text{one radian} = 57.296^\circ$$

$$l = \sqrt{h^2 + c^2/4}$$

$$c = 2\sqrt{2rh - h^2}$$

$$r = \frac{4h^2 + c^2}{8h}$$

$$h = r - \sqrt{r^2 - c^2/4}$$



$$I \text{ about a diameter} = \frac{\pi d^3}{64} = .0491d^3$$

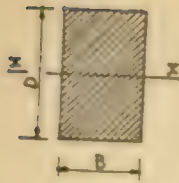
$$\begin{aligned} \text{Side of a square having periphery} \\ \text{equal to circumference of circle} &= \frac{r\pi}{2} \end{aligned}$$

$$\begin{aligned} \text{Diameter of a circle circumscribed} \\ \text{about a square} &= \text{side of square} \\ &\times 1.41421. \end{aligned}$$

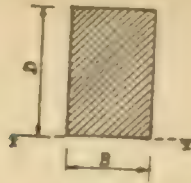
AREAS OF SMALL CIRCLES ADVANCING BY 32nds OF AN INCH

Diameter in inches	Area sq. inches	Diameter in inches	Area sq. inches	Diameter in inches	Area sq. inches	Diameter in inches	Area sq. inches
1 1/32	.0008	9 3/32	.0621	3 7/12	.2217	25 3/32	.4704
1 1/16	.0031	5 1/16	.0767	3 1/16	.2405	19 1/16	.5163
3 1/32	.0069	11 3/32	.0928	19 3/32	.2769	27 3/32	.5591
1 1/8	.0123	3 8	.1104	5 8	.3064	7 8	.6013
5 3/32	.0162	13 3/32	.1296	21 3/32	.3382	29 3/32	.6450
3 1/16	.0276	7 1/16	.1503	11 1/16	.3712	15 1/16	.6903
7 3/32	.0376	15 3/32	.1726	23 3/32	.4037	31 3/32	.7371
1 1/4	.0491	1 2	.1963	3 4	.4418	1	.7854

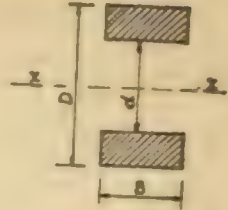
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$$I_{xx} = \frac{BD^3}{12}$$



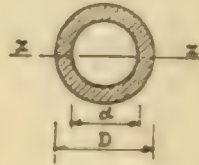
$$I_{yy} = \frac{BD^3}{12}$$



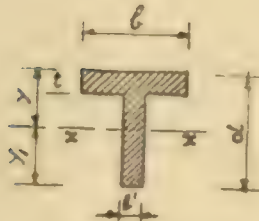
$$I_{xx} = \frac{B(D^3 - d^3)}{12}$$



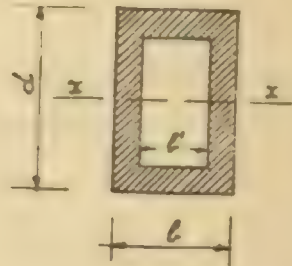
$$I_{xx} = \frac{\pi D^4}{64} = 0.0491 D^4$$



$$I_{xx} = \frac{\pi (D^4 - d^4)}{64} = 0.0491 (D^4 - d^4)$$



$$I_{xx} = \frac{b'y^3 + by^3 - (b-b')(y-t)^3}{3}$$



$$I_{xx} = \frac{bh^3 - b'h'^3}{12}$$



$$I_{xx} = \frac{BD^3}{12}$$



$$I_{yy} = \frac{BD^3}{36}$$



$$I_{xx} = \frac{BD^3}{4}$$

Moments of Inertia of Sections.

GENERAL DATA, TABLES, ETC.

Weights & Measures.

8 Ruttees	=	1 masha	=	$3/175$ dr.	Avois
12 mashas	=	1 Tola	=	$12/175$	"
5 Tolas	=	1 chattak	=	$2\frac{2}{35}$ ozs.	"
16 chattaks	=	1 seer	=	$2\frac{2}{35}$ lbs.	"
40 seers	=	1 maund	=	$82\frac{2}{37}$ lbs.	"
4 chattaks	=	20 Tolas	=	$2\frac{2}{35}$ lbs.	
4 Paus	=	1 seer			
5 seers	=	1 Pansari			

16 Drams	=	1 ounce
16 ounces	=	1 pound
14 pounds	=	1 stone
28 pounds	=	1 quarter
112 pounds	=	1 hundredweight (cwt.)
20 cwt.	=	1 Ton.

4 inches	=	1 hand
9 inches	=	1 span
12 inches	=	1 foot
3 feet	=	1 yard
5 feet	=	1 pace
6 feet	=	1 fathom
$5\frac{1}{2}$ yards	=	1 rod pole
4 poles	=	1 chain
10 chains	=	1 furlong
8 furlongs	=	1 mile (one nautical mile=6080 ft.)
3 miles	=	1 league 1 Knot = 1 nautical mile/hour.)

144 square inches	=	1 square foot
9 square feet	=	1 square yard
$30\frac{1}{2}$ square yards	=	1 square perch
40 perches	=	1 rood
4 roods	=	1 acre
640 acres	=	1 square mile
an acre	=	4840 sq. yds.

cubic foot	=	1728 cubic inches
cubic yard	=	27 cubic feet
stack of wood	=	108 cubic feet.

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Metric Measures.

(1) Length :

Millimeter (m.m.)	=	.039370 inches
Centimeter = 10 ¹ m.m.	=	.393704 "
Decimeter = 10 ² m.ms	=	3.937043 ..
Meter = 10 ³ m.ms	=	39.370428 "
Decimeter = 10 ⁴ m.ms	=	393.70428 "
		= 32.80869 ft.
Hectometer = 10 ⁵ m.ms	=	= 328.0869 ft.
Kilometer = 10 ⁶ m.ms	=	= 3280.869 ft.

(2) Area

Square millimeter (m.m ²)	=	.001550 sq. inches.
Sq. Centimeter = 10 ² sq. m.ms	=	.1550 sq. inches
Sq. Decimeter = 10 ⁴ sq. m.ms	=	15.5003 sq. inches
Sq. Meter = 10 ⁶ sq. m.ms	=	1550.03 sq. inches
		= 10.764 s.ft.
Sq. Kilometer = 10 ¹² sq. m.ms	} =	10764101 s.ft.
= 10 ⁶ sq. meters.		or 247.11 acres.

(3) Capacity.

Millilitre	=	.0610254 Cubic inches.
Centilitre	= 10 Millilitres	= .610254 Cubic in.
Litre	= 10 ³ millilitres	= 61.0254 Cubic in.
Kilolitre	=	35.3156 Cubic ft.

(4) Weight.

Milligramme	= $\frac{1}{10}$ Centigramme	= $\frac{1}{10^3}$ gramme =	.015432 grains.
Gramme	=	=	0.03527 oz.
Kilogramme	= 10 ³ grammes	=	2.2046 lbs.
Tonne	= 1000 Kilogrammes	=	.9843 Tons.

(5) Volume.

1 Cubic Centimeter (c.c.)	=	.06103 Cubic inches.
1 Cubic Meter	= 1,000,000 c.cs	= 35.3156 Cubic ft.
		= 1.31 Cubic yds.

GENERAL DATA, TABLES, ETC.

Conversion factors.

Multiply by	To convert	To	
7000	Pounds (avoir)	Grains (troy)	.000143
28.35	Ounces (avoir)	Grammes	.0352
.065	Grains	-do-	15.38
50.8	Cwts.	Kilogrammes	.01968
1016.0	Tons	-do-	.000984
4.546	Gallons	Litres	.22
10	Gallons of water	Pounds	.1
.454	Pounds of water	Litres	.2202
70.3	lb/sq. inch	gms/sq. cm.	.0142
2.3	-do-	Head of water ft.	.434
0.7	-do-	" M.	1.4285
.068	-do-	atmospheres	14.7
1.575	Tons/sq. inch	Kgm./mm ²	.635
4.883	Lbs/sq. ft.	Kgm./m ²	.205
.593	Lbs./Cubic yd.	Kgm. m ³	1.686
16.02	Lbs./Cubic ft.	Kgm/m ³	.0624
.0998	Lbs./gal.	Kgm./Litre	10.02
.138	Foot lbs.	Kgm. meters	7.23
.33	Foot Tons	Tonnes meters	3
1014	H. P.	Force-de-cheval	.9861
746	"	Watts	.00134
33000	"	Ft. lbs/min	—
76	"	Kg. m/sec.	.01316
44	Watts	Ft. lbs./min	.0227
0.1	"	Kg m/sec.	10
0.252	Heat units	Calories	3.97
14.7	Atmospheres	Lb./Sq. inch	.068
0.70	German candles	English Candles	1.1111
9.55	Carcels	Candles	.1047
.737	Joules	Ft. lbs.	1.357
88	Miles/hour	Ft./min	.01134
	To obtain	From	multiply by above.

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Multiply by	To Convert	To	
197	meters/sec	Ft/min	.001508
1.8	C.H.O.	B.Th.U.	.5555
0.0208	Centipoise	Lbs/m ² sec	.48
1.488	lbs/ft	kgm litre	0.672
0.496	lbs/yd	-do-	2.016
3333.33	tons/ft	-do-	0.0003
1111.11	tons/yd	-do-	0.0009
0.2818	lb/mile	kgm/kilometer	3.548
10.936	tons/sft	tonnes/meter ²	0.0914
1.215	tons/syd	-do-	0.823
1.329	tons/cu. yd.	tonnes/m ³	0.752
0.01426	grains/gallon	gm/litre	70.12
48.905	gallons/sft	litres/m ²	0.0204
25.8	inch/tons	kgm/meters	0.0387
0.477	lbs/H.P.	kgm per cheval	2.235
0.0916	sft/H.P.	m ² cheval	10.913
0.0279	cft/H.P.	m ³ /cheval	35.806
2.713	Heat units/H.P.	calories/m ²	0.369
	To obtain	From	Multiply by above

METRIC EQUIVALENTS OF FEET & INCHES

(figures indicate metres)

Feet & Inches	0	1	2	3	4	5	6	7	8	9	10	11	12
0	0	305	610	914	1-219	1-524	1-829	2-133	2-438	2-743	3-048	3-352	3-657
1	0254	330	635	940	1-244	1-549	1-854	2-158	2-463	2-768	3-073	3-378	3-683
2	0508	350	660	965	1-269	1-573	1-880	2-184	2-489	2-794	3-099	3-403	3-708
3	0762	361	666	991	1-295	1-600	1-905	2-209	2-514	2-819	3-124	3-429	3-733
4	1016	406	711	1-016	1-320	1-626	1-931	2-235	2-540	2-844	3-150	3-454	3-759
5	1270	422	737	1-041	1-346	1-651	1-956	2-260	2-565	2-870	3-175	3-479	3-784
6	1524	437	762	1-066	1-371	1-676	1-981	2-285	2-590	2-895	3-200	3-505	3-810
7	1778	453	787	1-092	1-397	1-702	2-007	2-311	2-616	2-921	3-226	3-530	3-835
8	2032	468	813	1-117	1-422	1-727	2-032	2-336	2-641	2-946	3-251	3-555	3-860
9	2286	483	838	1-142	1-448	1-753	2-057	2-361	2-667	2-972	3-276	3-581	3-886
10	2540	500	864	1-168	1-473	1-778	2-083	2-387	2-692	2-997	3-302	3-606	3-911
11	2794	514	889	1-193	1-498	1-803	2-108	2-412	2-717	3-022	3-327	3-632	3-936

ENGLISH EQUIVALENTS OF CMS & MILLIMETERS

	0	1	2	3	4	5	6	7	8	9	10 cms.
m/m	0	0987	1974	2961	3948	4935	5922	6909	7896	8883	9870 inches
1	0394	1181	2168	3155	4142	5129	6116	7103	8090	9077	
2	0787	1574	2561	3548	4535	5522	6509	7496	8483	9470	
3	1181	2168	3155	4142	5129	6116	7103	8090	9077		
4	1574	2561	3548	4535	5522	6509	7496	8483	9470		
5	1968	2955	3942	4929	5916	6903	7890	8877	9864		
6	2362	3349	4336	5323	6310	7297	8284	9271			
7	2756	3743	4730	5717	6704	7691	8678	9665			
8	3150	4137	5124	6111	7098	8085	9072				
9	3543	4530	5517	6504	7491	8478	9465				



GENERAL DATA, TABLES, ETC.

METRIC EQUIVALENTS: (millimetres from inches and sixteenths)

Inch	0	1-16	1-8	3-16	1-4	5-16	3-8	7-16
0		1-58	3-17	4-76	6-35	7-93	9-52	11-11
1	25-400	25-48	26-67	30-16	31-74	33-33	34-92	36-51
2	50-799	52-38	53-97	55-56	57-14	58-73	60-32	61-91
3	75-199	77-78	79-37	80-96	82-54	84-13	85-72	87-31
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CONCRETE ENGINEERS' HANDBOOK

METRIC EQUIVALENTS: (millimeters from inches and sixteenths)

Inch	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16
0	12.70	14.29	15.87	17.46	19.05	20.63	22.22	23.81
1	25.40	29.06	31.75	34.44	37.14	39.83	42.52	45.21
2	50.80	58.12	63.50	68.89	74.28	79.67	85.06	90.44
3	76.20	87.17	95.25	103.33	111.41	119.49	127.57	135.65
4	101.60	117.15	126.98	136.81	146.64	156.47	166.30	176.13
5	127.00	145.75	156.48	167.21	177.94	188.67	199.40	210.13
6	152.40	174.26	186.75	199.24	211.73	224.22	236.71	249.20
7	177.80	202.70	216.75	230.80	244.85	258.90	272.95	287.00
8	203.20	230.33	245.25	260.17	275.10	290.02	304.94	319.87
9	228.60	258.44	274.25	290.06	305.91	321.76	337.61	353.46
10	254.00	286.55	303.17	319.96	335.81	351.66	367.51	383.36
11	279.40	314.66	332.25	345.81	361.66	377.51	393.36	409.21
12	304.80	342.77	360.75	371.66	387.51	403.36	419.21	435.06
13	330.20	370.88	388.75	403.50	419.35	435.20	451.05	466.90
14	355.60	398.99	416.75	429.35	445.20	461.05	476.90	492.75
15	381.00	427.10	444.75	455.20	471.05	486.90	502.75	518.60
16	406.40	455.21	472.75	481.05	496.90	512.75	528.60	544.45
17	431.80	483.32	499.75	506.90	522.75	538.60	554.45	570.30
18	457.20	511.43	527.75	532.75	548.60	564.45	580.30	596.15

GENERAL DATA, TABLES, ETC.

TABLE OF ENGLISH WEIGHTS EXPRESSED IN INDIAN WEIGHTS

English	Indian	English	Indian	English	Indian	English	Indian
Lbs.	2	Mds. Srs 1	16	21 31	34	925 22	90 2450 0
	4	2	16	24 20	36	980 0	92 2504 18
	6	3	Tons. 1	27 9	38	1034 18	94 2558 36
	8	4	2	34 18	40	1088 36	96 2612 12
	10	5	3	31 27	42	1143 12	98 2667 31
	12	6	4	106 36	44	1197 31	100 2722 9
	14	7	5	136 4	46	1252 9	200 3444 18
	16	8	6	163 12	48	1306 27	400 10888 36
	18	9	7	190 22	50	1361 4	500 13311 4
	20	10	8	217 31	52	1415 22	1000 27322 9
	22	11	9	245 0	54	1470 0	
	24	12	10	272 9	56	1524 18	100 Mds=3 673 Tons.
	26	13	11	299 18	58	1578 36	1 Ton =27.22 Mds
Qrta.	1	14	12	326 27	60	1633 18	1 Md. =82.29 Lbs.
	2	27	13	353 36	62	1687 31	
	3	1 1	14	381 4	64	1742 9	
Cnts.	1	1 14	15	408 12	66	1796 27	
	2	2 20	16	435 22	68	1851 4	
	3	4 3	17	462 31	70	1905 22	
	4	5 18	18	490 0	72	1960 0	
	5	6 32	19	517 9	74	2014 18	
	6	8 7	20	544 18	76	2068 36	
	7	9 21	22	596 36	78	2123 12	
	8	10 36	24	653 12	80	2177 31	
	9	12 10	26	707 31	82	2232 9	
	10	13 24	28	762 9	84	2286 27	
	12	16 12	30	816 27	86	2341 4	
	14	18 2	32	871 4	88	2395 22	

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